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DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES 881 HILLSIDE AREA (OU-1) TECHNICAL MEMORANDUM #11

Draft Final

Department of Energy
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM

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LIST OF ACRONYMS

ARAR	applicable or relevant and appropriate requirement
BRA	Baseline Risk Assessment
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
CRS	Colorado Revised Statutes
DOE	Department of Energy
EE	Environmental Evaluation
EPA	Environmental Protection Agency
FML	flexible membrane liner
FR	Federal Register
FS	Feasibility Study
GRA	general response action
IAG	Interagency Agreement
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
MCL	maximum contaminant level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	operation and maintenance
OU-1	Operable Unit 1
OU-2	Operable Unit 2
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PHE	Public Health Evaluation
PRG	preliminary remediation goal

LIST OF ACRONYMS (Continued)

RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RFP	Rocky Flats Plant
RI	Remedial Investigation
ROD	Record of Decision
SID	South Interceptor Ditch
TBC	to-be-considered
TSDF	treatment, storage, and disposal facility
UHSU	upper hydrostratigraphic unit
USC	United States Code
UV	ultraviolet
VOC	volatile organic compound

1.0 INTRODUCTION

The purpose of this Technical Memorandum is to document the process by which remedial action alternatives were developed and screened for the 881 Hillside Area (Operable Unit 1 [OU-1]) of the Department of Energy's (DOE) Rocky Flats Plant (RFP). The memorandum is written in accordance with the Rocky Flats Interagency Agreement (IAG) dated January 1991 (IAG 1991). The IAG requires that a summary of the assembled remedial action alternatives and their related action-specific applicable or relevant and appropriate requirements (ARARs) be included in a technical memorandum for submittal to the Environmental Protection Agency (EPA) and/or the Colorado Department of Health (CDH) for review. To support the development of remedial action alternatives, this technical memorandum includes a summary of the technology and process option identification, screening, and evaluation process, that was employed prior to assembling alternatives. Technologies and process options for remediation of radionuclide, polynuclear aromatic hydrocarbon (PAH), and polychlorinated biphenyl (PCB) contaminants in soils are also included with this report as Attachment I. Surface soil contaminants will be addressed administratively under Operable Unit 2 (OU-2); however, this information is summarized in the attachment to present data collected during the course of the OU-1 Corrective Measures Study/Feasibility Study (CMS/FS).

Alternatives have been assembled that address the remedial action objectives (RAOs) presented in *Technical Memorandum #10 - Development of Remedial Action Objectives* (DOE 1994). This previous technical memorandum describes in detail the identification of appropriate RAOs and preliminary remediation goals (PRGs) for the 881 Hillside Area. In addition, details concerning the site history and characterization can be found in the Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) report for OU-1 (DOE 1993). Information contained in both of these documents has been summarized where necessary throughout this report. However, in order to avoid duplication of effort, this information has been kept to a minimum. The final OU-1 CMS/FS report will include both technical memorandums and will be made available as an accompanying document to the RFI/RI report.

Because this technical memorandum is only intended to summarize alternative development, technical details concerning each alternative have been included to the extent necessary to conduct the initial screening of alternatives and to identify potential action-specific ARARs. Alternatives that survive the screening process will be analyzed in much greater detail during the detailed analysis of alternatives, which will be presented in the complete OU-1 CMS/FS report.

2.0 IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND REPRESENTATIVE PROCESS OPTIONS

This section discusses the method by which technologies and process options were identified, screened, and evaluated for the development of remedial action alternatives. According to the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a), this method consists of the following steps (where CERCLA refers to the Comprehensive Environmental Response, Compensation, and Liability Act):

- Develop media-specific RAOs
- Develop media-specific general response actions (GRAs)
- Identify volumes and/or areas of the media which require GRAs
- Identify and screen technologies and process options applicable to each GRA
- Evaluate process options within each technology type to select a representative option for the development of remedial action alternatives

These steps are described in greater detail in the following subsections, with the exception of the development of RAOs. RAOs and associated PRGs are discussed in detail in Technical Memorandum #10. Briefly the RAOs for OU-1 are:

1) Prevent the inhalation of, ingestion of, and/or dermal contact with volatile organic compounds (VOCs) (from chlorinated solvents) and inorganic contaminants in groundwater that would result in a total excess cancer risk greater than 10^{-4} to 10^{-6} for carcinogens and/or a hazard index greater than or equal to one for non-carcinogens.

2) Prevent the inhalation of, ingestion of, and/or dermal contact with PAHs, PCBs, and radionuclides in surface soil hotspots that would result in a total excess cancer risk greater than 10^{-4} to 10^{-6} for carcinogens, and/or a hazard index greater than or equal to one for non-carcinogens.

3) Prevent exposure to carcinogenic radionuclides in surface soil hotspots that would result in an excessive short-term exposure to a human receptor.

These RAOs were used to identify GRAs for OU-1 and to guide the development of remedial action alternatives. As previously mentioned, surface soil contaminants will be dealt with administratively under OU-2; therefore, the second and third RAOs listed above apply only to the localized surface soil hotspots which are addressed as part of all groundwater alternatives.

2.1 General Response Actions

GRAs are general waste management strategies that are designed to satisfy remedial action objectives. Examples of GRAs include treatment, containment, excavation, extraction, and a variety of similar actions used singly or in combination. GRAs are medium-specific and therefore require that a list of GRAs be developed for each medium of concern. In the case of OU-1, only the medium of groundwater requires GRAs, due to the limited areal extent of the surface soil hotspots.

Preliminary information obtained from the RFI/RI supplementary field investigation (radiological surface soil survey) indicates that there exist four surface soil locations in OU-1 with elevated radionuclide concentrations. This survey found that the areal extent of each "hotspot" was roughly 1 ft^2 or less and that the depth of contamination ranged from 1 to 4 feet. A conservative estimate would result in a maximum of 12.5 ft^3 of contaminated soil requiring removal. It is assumed that implementation of any groundwater GRA presented below would include removal and temporary storage of this contaminated soil. GRAs are therefore not included for this medium.

2.1.1 Medium-Specific General Response Actions

The GRAs identified for the OU-1 groundwater medium are no action, institutional controls, containment, removal, in situ treatment of chlorinated solvents, ex situ treatment of chlorinated solvents, in situ treatment of inorganics, and ex situ treatment of inorganics. These GRAs target the contaminant groups discussed in the RAOs for groundwater. Surface soil hotspot RAOs would be met by removal of the soil at the hotspot locations prior to implementation of any groundwater remedial actions. A brief description of each of the GRAs is provided below:

- *No action* - Required by CERCLA as a benchmark for comparison against other remedial action alternatives. Implies that no direct action will be taken to alter the existing situation, other than short- and long-term monitoring of site conditions.

- *Institutional controls* - Refers to controls based on legal and/or management policies which minimize the public's exposure to potential contaminants. Examples include controlling site access, restricting land use, and restricting access to groundwater.

- *Containment* - For groundwater, containment would consist of actions which minimize the flux of vapor-phase VOCs to the surface, and/or minimize the migration of groundwater contaminants across site boundaries.

- *Removal* - For OU-1, removal implies extraction of contaminated groundwater for treatment in the existing ultraviolet (UV)/peroxide system. The excavation of soils to locate and extract groundwater is also included under this GRA.

- *In Situ Treatment of Chlorinated Solvents* - In general, in situ treatment technologies seek to treat contaminants in place without extraction or removal of large volumes of groundwater. Treatment would seek to remove, destroy, and/or immobilize contaminants via biological, chemical, or physical means. Note that this category includes extraction technologies such as soil vapor extraction and in situ steam stripping, which include above ground treatment of off-gas.

- *Ex Situ Treatment of Chlorinated Solvents* - This response is similar to in situ treatment with the exception that contaminants would have to be extracted/removed prior to treatment. Treated groundwater would be discharged via existing channels (i.e., the existing UV/peroxide treatment system).

- *In Situ Treatment of Inorganics* - This GRA is similar to that shown for in situ treatment of chlorinated solvents. In this case, treatment would seek to immobilize contaminants via chemical or physical means.

- *Ex Situ Treatment of Inorganics* - Similar to the preceding GRA, this GRA would seek to extract and/or immobilize contaminants via chemical or physical means. Treated groundwater would be discharged via existing channels (i.e., the existing UV/peroxide treatment system).

2.1.2 Volume and Area Estimates

In order to properly apply appropriate GRAs to each medium of concern, volume and area estimates are required to ensure that GRAs identified for a medium are capable of meeting the remedial action objectives for that medium. For the OU-1 CMS/FS, volume and area estimates were calculated based on the results of the OU-1 Phase III RFI/RI report. Both surface soils and groundwater were examined, although only groundwater and surface soil hotspot remediation is being considered under OU-1. Surface soil volume and area estimates for low-level plutonium and PAH contaminants are provided for information purposes and to support preparation of the OU-2 CMS/FS report.

Surface soil characterization data, as presented in the RFI/RI report, indicates that PAH contamination exists over large areas of OU-1, including areas outside of the OU boundaries. In order to approximate the areal extent of contamination, the data was used to delineate boundaries outside of which no PAHs were detected. The boundaries selected to define this area resulted in a rectangular "plot" which extended from the northeast corner of Building 881 down to the South Interceptor Ditch (SID), then followed the SID east to a point just outside of surface sampling points RA025 and RA024. These sampling points mark the eastern edge of the defined "plot" with Building 881 defining the north and west edges, and sampling point RA014 defining the south edge. These sampling locations can be seen on Figure 2-1. The area calculated for this "plot" was approximately 1,107,270 ft^2 (123,030 yd^2) or 25.4 acres. (Note that this area does not take into account the disturbance caused by installation of the French Drain.) Since only the top two inches of soil were sampled during the surface soil sampling effort, this layer was assumed to be the amount of material that would have to be removed during any excavation option to ensure that all surface contaminants were collected. This corresponds to a total surface soil volume of 1,107,270 ft^2 times 0.167 ft (two inches), or 184,545 ft^3 (6,835 yd^3).

The OU-2 CMS/FS will examine this volume in greater detail when this medium is addressed, to verify whether the assumption that surface soil contamination does not appear below two inches is accurate, and to determine the effect the French Drain installation had on surrounding contaminant concentrations. This estimate is also assumed to be applicable to the wide-spread plutonium contamination in OU-1; however, the calculation was based on PAH sampling locations since the plutonium contaminant "plume" originates in OU-2 and therefore

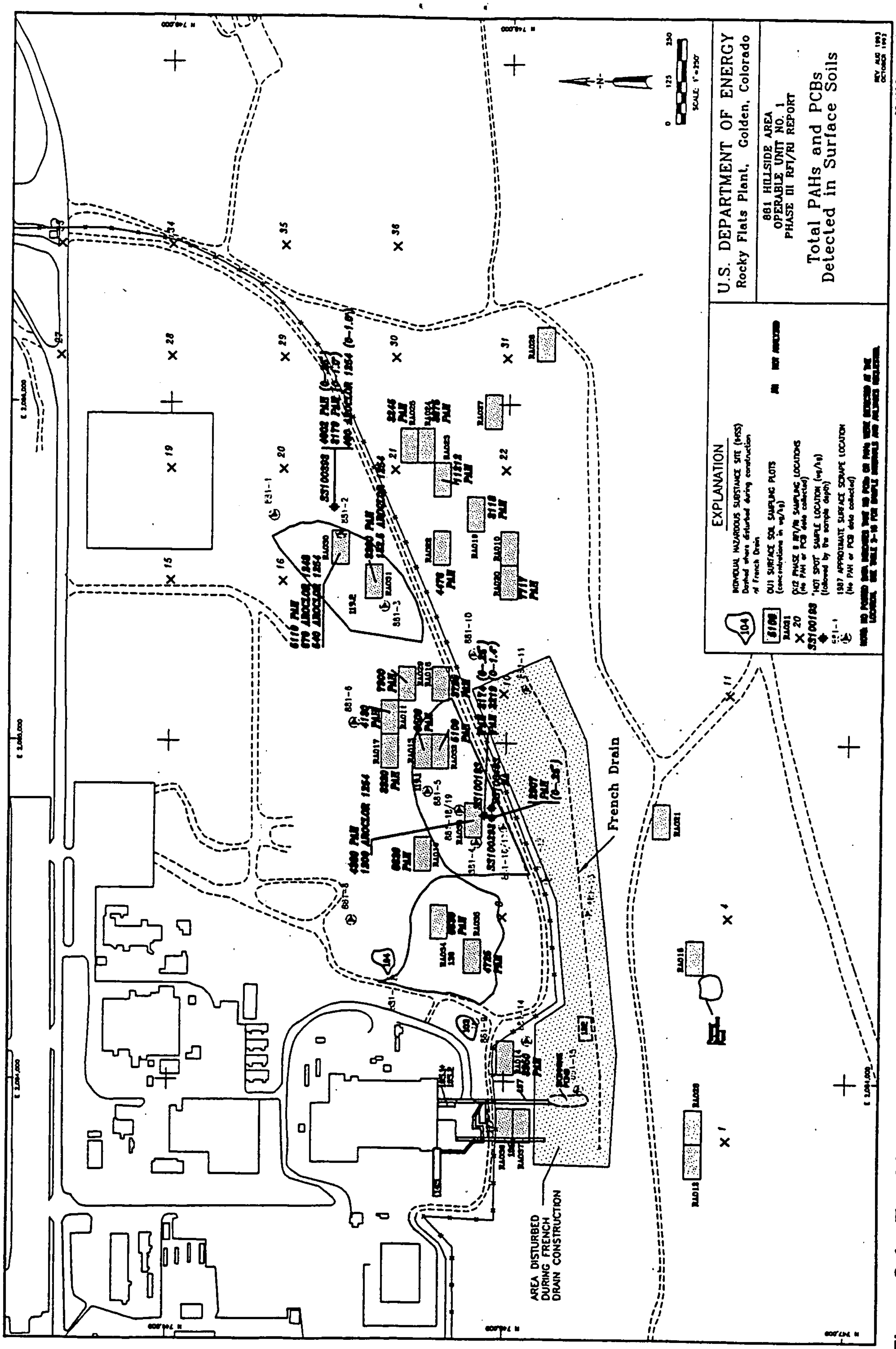


Figure 2-1. Total PAHs and PCBs Detected in Surface Soils (from OU-1 RFI/RI)

extends beyond OU-1 surface soil sampling boundaries. An accurate determination of the areal extent of plutonium contamination will have to consider the PRGs for both plutonium and americium.

Based on the results of the OU-1 RFI/RI report, and the Baseline Risk Assessment (BRA) in particular, contaminated groundwater in OU-1 was found to contribute a significantly higher risk to those receptors exposed to groundwater found beneath a specific portion of Individual Hazardous Substance Site (IHSS) 119.1, than to receptors exposed to groundwater from other locations in OU-1. IHSS 119.1 was designated a source location in the Public Health Evaluation (PHE) for this reason. Other areas of the operable unit contain groundwater contaminant concentrations above PRGs; however, the concentrations are greatest at this IHSS.

The quantity of groundwater requiring remedial action in the IHSS 119.1 source area was calculated using computer codes which evaluated a three-dimensional model of the geology encompassing the source wells. The wells which were used to identify and delineate this location are 0487, 0974, 1074, 4387, 32591, and 37991.

Figure 2-2 depicts the first quarter (1992) saturated thickness map for OU-1. This data was used to determine the amount of soil which contained contaminated groundwater in the source location. This value was then multiplied by the average porosity at the location to estimate the pore volume of contaminated groundwater to be addressed by remedial actions which target the source, although more than one pore volume would likely have to be removed to achieve RAOs. Using an average porosity of 0.10 (DOE 1993), the volume of groundwater estimated to be present in the southwest corner of IHSS 119.1 is 80,000 gallons.

In addition, the Phase III RFI/RI report estimated the amount of available groundwater in all of OU-1 to be between 5 and 5.8 acre-feet, or 1.6 to 1.9 million gallons. Both the volume of groundwater estimated to be beneath IHSS 119.1, and the volume of groundwater contained within the OU-1 boundaries, are used to estimate remediation requirements; although, it should be noted that groundwater elevations in OU-1 are highly dependent on seasonal variations in precipitation.

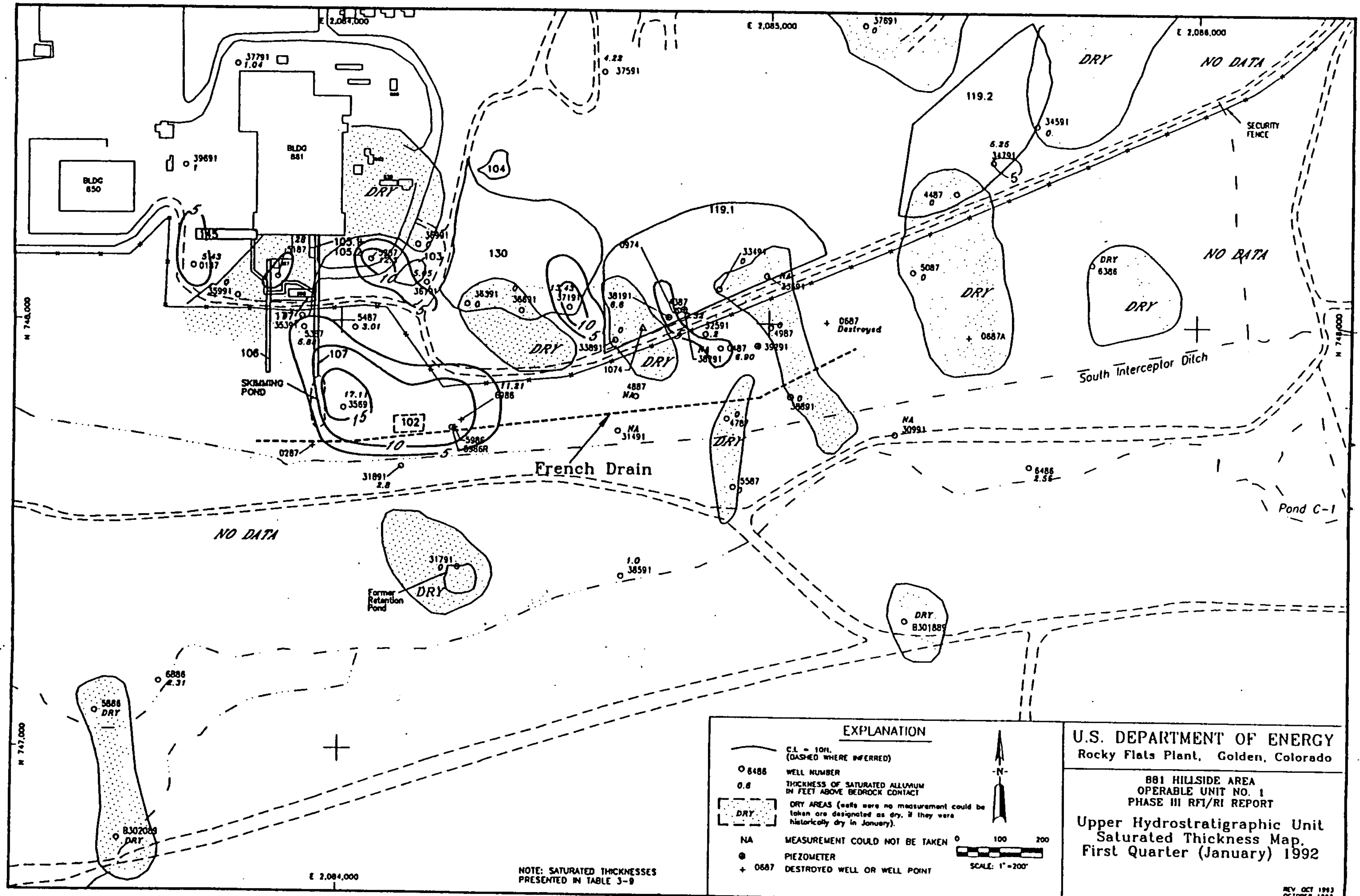


Figure 2-2. UHSU Saturated Thickness Map (from OU-1 RFI/RI)

2.2 Identification and Screening of Technologies and Process Options

The objective of this subsection is to document the identification and screening of technologies and process options that resulted in the selection of representative process options for the development of alternatives. As used here, the terms *technology* or *technology type* refer to general technological categories applicable under a given GRA, while *process options* refer to specific remedial actions that are available for consideration within a particular technology type. Also, a process option that is chosen for development of an alternative is considered a representative process option only. It does not necessarily mean that the alternative will be implemented using that specific process option. On the contrary, the process option selected represents a class of options that could potentially be implemented.

The process of identifying, screening, and evaluating technologies and process options is based on CERCLA guidance and generally consists of the following steps:

- A review of the RAOs, specifying the contaminants and media of concern, exposure pathways, and preliminary remediation goals that permit development of treatment and containment alternatives for remediation. The preliminary remediation goals are developed on the basis of chemical-specific ARARs, when available, other pertinent information (e.g., RfDs), and site-specific, risk-related factors.

- A review of the general response actions for each medium of interest defining institutional actions, containment, removal, treatment, disposal, or other actions, singly or in combination, that could be used to satisfy the remedial action objectives for the site.

- An evaluation of what technologies to include, based on available site information and the identification of volumes or areas of media to which general response actions might be applied, taking into account the requirements of the remedial action objectives and the chemical and physical characteristics of the site.

- The identification and screening of technologies and process options applicable to each general response action and the elimination of those that could not be technically implemented at the site.

- An evaluation of each process option considering its effectiveness, implementability, and cost relative to other process options of the same technnology type and GRA. This evaluation results in the selection of representative process options for development into remedial action alternatives.

Several references were used to identify potential technologies and process options for inclusion in the CMS/FS. EPA guidance documents, technical publications, and proceedings were used, as well as DOE guidances, independent technical texts, and recent technical publications from a variety of journals. Engineering experience was also used to prepare a list of potential remedial technologies based on the established contaminants and corresponding media.

2.2.1 Screening Criteria

Once a list of potential technologies was prepared, the next step in the identification and screening process was to reduce the number of potential technologies and process options to a smaller and more representative number that would be appropriate for the preparation of remedial alternatives. This step was accomplished by screening technologies and process options on the basis of technical implementability. The implementability of a technology or a process option was determined according to the existing site conditions, the current contaminants, and the nature of the technology (i.e. was there enough information available on the technology to evaluate its applicability). In accordance with CERCLA, process options and entire technology types were eliminated from further consideration during this screening.

2.2.2 Initial Screening of Technologies and Process Options

The initial screening of technologies and process options is presented in Figure 2-3. The figure shows the GRAs that were identified for the groundwater medium, the technologies chosen to satisfy each GRA, and the process options identified that could represent each technology. Each process option is also accompanied by a summary description of the option and a comment which documents the reason for eliminating or maintaining that process option.

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
No Action	None	Not applicable	Required for consideration by the National Oil and Hazardous Substances Contingency Plan	Potentially applicable as a baseline against which other GRAs/alternatives can be compared during detailed analysis
	Monitoring	Long-term groundwater monitoring	Monitoring of groundwater in operable unit after remediation, or as part of an institutional control period associated with the no action alternative	Potentially applicable for monitoring site-specific groundwater conditions
		Short-term groundwater monitoring	Monitoring of groundwater in operable unit during remediation activities	Potentially applicable for monitoring site-specific groundwater conditions
Institutional Controls	Access Restrictions	Legal restrictions on access	Restrictions on present and future access to land prevent unauthorized access to groundwater source	Potentially applicable for controlling access to groundwater sources and/or exposure to COCs
		Fencing or other physical barriers	Fencing, security posts, limited roads, and other various physical restrictions limit access to groundwater sources	Potentially applicable for controlling access to groundwater sources and/or exposure to COCs
		Legal restrictions on land use	Restrictions on present and future use and/or purchase of land; includes actions such as zoning and deed restrictions	Potentially applicable for controlling use of land affected by contaminated groundwater zones

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

Figure 2-3. Initial Screening of Technologies and Process Options

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Containment	Vertical Subsurface Flow Control	Subsurface Drains	Gravity driven collection system which is used to redirect groundwater flow and/or collect it for treatment	Potentially applicable; includes possibility of modifying existing french drain system for use during remediation
		Grout Curtains	Grout "columns" are injected vertically into the soil in close proximity of each other to form an impermeable wall	Would not contribute additional containment because of existing low hydraulic conductivity
		Slurry Walls	A soil/bentonite or cement grout wall formed by backfilling a trenched area; has a lower permeability than native soils	Not implementable because of hillside stability concerns; trenching may lead to slumping of native soils
		Sheet Pilings	Steel forms which are driven into the ground and joined to form a barrier which is impermeable to groundwater	Very difficult to implement due to proximity of bedrock; not widely used or accepted in cleanups
		Cryogenic Barrier	A section of ground is frozen to reduce its permeability thus limiting the mobility of contaminants through the area	Only applicable as a short-term measure to control the migration of contaminants through an area
	Horizontal Subsurface Flow Control	Grout Injection	Grout is injected in a horizontal pattern beneath surface soils to limit vertical migration of VOCs from groundwater	Not applicable for remediation of VOCs in groundwater in fractured bedrock
		Block Displacement	Innovative use of grout forms perimeter barrier around waste while displacing waste upwards to block pathway	Not applicable for control of VOCs that result from volatilization of groundwater contaminants, nor for use in fractured bedrock
	Vapor Containment	Surface Cap	Compacted soil and bentonite cap used to reduce water infiltration to subsurface, and to contain VOC emissions	Potentially applicable for reducing vapor phase transport to surface structures
		Environmental Isolation Enclosure	One of several types of temporary structures used to contain/collect fugitive vapors and dust during remedial action activities; utilizes additional off-gas treatment	Potentially applicable for scenarios which would involve excavating soils to reach groundwater

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

Figure 2-3. Initial Screening of Technologies and Process Options (Cont.)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Removal	Passive Removal	Subsurface Drains	Gravity driven collection system which is used to redirect groundwater flow and/or collect it for treatment	Potentially applicable; includes possibility of modifying existing french drain system for use during remediation
	Active Removal	Horizontal and/or Vertical Extraction Wells or Sumps	Systems consisting of wells, installed either vertically or horizontally, that are used to collect/recharge groundwater	Potentially applicable for removing contaminated water for treatment, for diverting groundwater flow, or for lowering localized water table
	Excavation	Loader/Excavator/Dozer	Tractor/wheel mounted vehicles commonly used to excavate or move large amounts of soil; can operate at various depths.	Potentially applicable for removal of subsurface soils to locate groundwater hotspots
In-Situ Treatment of Chlorinated Solvents	Biological	Bioremediation	Destroy organics through microbial degradation; methanotropic process is specific to chlorinated solvents	Potentially applicable for in situ treatment of organic compounds in groundwater; however, degradation products may be more harmful than original contaminants
	Chemical	Polymerization	Catalyst injected into groundwater causes polymerization of organic monomers, forming a gel-like, non-mobile mass	Contact between reagent and groundwater is eventually overly hindered by the formation of the gel-like mass
		Chemical Oxidation	Breakdown of organics using chemicals which are typically introduced into the subsurface via injection wells or by drilling directly into the edge or within a contaminant plume	Difficult to apply because of concerns over injecting additional chemicals into the subsurface which may result in the formation of hazardous oxidation products
	Physical	Hot Air/Steam Stripping with Mechanical Mixing	Hot air or steam is injected into the groundwater to promote the volatilization of VOCs which have low vapor pressures	Potentially applicable to remove VOCs which are less likely to be volatilized through conventional means
		Air Sparging	Pressurized air is injected below or within a contaminated groundwater plume to cause in situ stripping of VOCs	Potentially applicable for in situ treatment of VOCs in groundwater
		Vapor Extraction	Induced negative pressure above saturated zone collects volatilized contaminants for treatment	Potentially applicable for removal of VOCs from groundwater or for supporting other technologies (e.g. air sparging)
		Permeable Treatment Beds	A fixed bed containing treatment resins is placed down-gradient of a groundwater plume to treat water in situ	Potentially applicable for in situ treatment of organic compounds in groundwater (including VOCs in vadose zone), however, limited by site hydrogeology
		In Situ Adsorption w/Wells (proprietary process)	Adsorption of organic contaminants in groundwater through the use of proprietary resin beads placed in existing wells	Potentially applicable for in situ treatment of organic compounds in groundwater (including VOCs in vadose zone), but not implementable due to low hydraulic conductivity
		RF/Ohmic Heating	Contaminants volatilized and/or destroyed by energy absorbed from radio frequency or ohmic sources	Potentially applicable for in situ treatment of organic compounds, effectiveness not dependent on conductivity or presence of groundwater

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

Figure 2-3. Initial Screening of Technologies and Process Options (Cont.)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex-Situ Treatment of Chlorinated Solvents	Biological	Bioremediation	Destroy organics through microbial degradation; methanotropic process is specific to chlorinated solvents	Potentially applicable for ex situ treatment of organic compounds in groundwater; however, degradation products may be more harmful than original contaminants
	Chemical	Solvent Extraction	Removal of organics by mass transfer to an organic solvent which is mutually insoluble with the original solvent (water)	Not feasible for groundwater with low VOCs concentrations; solvent would still require treatment/disposal
		Ultraviolet Photolysis with Chemical Oxidation	UV radiation is applied to assist in oxidizing organic compounds using various oxidizing agents, thereby destroying them	Potentially applicable for destroying organic compounds in extracted groundwater; may include modification of existing UV/peroxide treatment system
	Physical	Gamma Irradiation	Innovative technology which decomposes organic compounds by destroying their chemical bonds using gamma irradiation	Not widely documented as to its use in the treatment of organic wastes; also not feasible for low contaminant levels
		Activated Carbon or Carbonaceous Adsorbents	Extracted groundwater is passed through activated carbon which adsorbs most of the organic contaminants	Potentially applicable for removing organic compounds from extracted groundwater; carbon could be disposed of or regenerated
		Air Stripping	Water is sprayed through a packed tower designed to increase its surface area to air ratio, thereby promoting volatilization	Potentially applicable for removing volatile organics compounds from extracted groundwater
		Membrane Processes	Application of an "osmotic" pressure forces contaminants to flow through semi-permeable membrane against diffusion	Not directly applicable for treatment of VOCs in groundwater; more commonly used to remove particulates
		Hot Air/Steam Stripping	Similar to air stripping but uses hot air or steam to remove VOCs which have relatively low vapor pressures	Potentially applicable for removing volatile organic compounds from extracted groundwater
		Evaporation	Concentration method used to drive off solvent from an aqueous waste stream using man-made and/or natural means	Not applicable as a stand-alone treatment technology; more often used as a pre-treatment step for a process
		Freeze Crystallization	Method of removing dissolved organic species by freezing the supporting matrix and crystallizing the solvent for separation	Only feasible for aqueous waste streams where organic contaminant concentrations are above 3 - 7 % by weight
	Thermal	Incineration	Destruction of organics through combustion with oxygen using a thermal and/or a catalytic process option	Generally not applicable for liquids treatment at low contaminant concentration levels
		Plasma Arc Discharge	Pyrolysis of organics by high temperature plasma induced through electrical discharge to carrier gas	Potentially applicable for destruction of refractory oragnics in extracted groundwater
		Catalytic Oxidation	Catalyst allows low temperature thermal degradation of halogenated hydrocarbons to carbon dioxide, water, and hydrogen chloride. Also destroys non-halogenated VOCs forming water and carbon dioxide	Potentially applicable for treatment of groundwater or air. Can produce acid off-gas

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

Figure 2-3. Initial Screening of Technologies and Process Options (Cont.)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
In-Situ Treatment of Inorganics	Physical	Electrokinesis	Electrodes are inserted in boreholes and a current passed through the media, causing migration of ions to the oppositely charged electrode where they are extracted by conventional pumping	Potentially applicable for the removal of metals from contaminated groundwater
Ex-Situ Treatment of Inorganics	Physical	TRU Clear (Proprietary Process)	A proprietary potassium ferrate solution is mixed with groundwater, precipitating transuranic and heavy metals	Potentially applicable for treatment of extracted groundwater; currently undergoing treatability studies at RFP
		Oxidation/Reduction	Chemicals are added to groundwater which alter the oxidation state of the metals, causing precipitation	Potentially applicable for treatment of extracted groundwater; however, limited by low treatment efficiency
		Ferrite Process	Ferrite particles sorb metals and precipitate out of solution	Potentially applicable for treatment of extracted groundwater; similar to TRU-Clear process mentioned above
		Magnetic Separation	A high gradient magnetic field is applied to groundwater, which forces polar metal ions out of solution onto collector plates	Conceivably applicable for treatment of extracted groundwater; however, not an established technology for groundwater treatment
	Chemical	Freeze Crystallization	Contaminated solution is evaporated to saturation and then crystallization is induced by heat removal	Not feasible for waste streams with low contaminant concentrations due to prohibitive energy costs
		Ion Exchange	Metal species exchanged for resin ions and bound onto ion exchange resin for disposal	Potentially applicable for treatment of some metals; however, not applicable to many metal species
		Evaporation	Contaminated waste volume reduced by evaporation of solution in which contaminants are dissolved/suspended	Not feasible for extracted OU1 groundwater due to prohibitive energy costs
		Membrane Processes	Metals concentrated by passing the contaminated solution through a semi-permeable membrane	Potentially applicable for treatment of extracted groundwater; however, may have prohibitive energy costs
		Electrocoagulation	Neutralization and precipitation of metallic ions is induced by creation of neutralizing ions using electrical current	Potentially applicable for treatment of extracted groundwater
		Precipitation	Removal of inorganics from aqueous phase by changing oxidation state through addition of chemicals or energy	Potentially applicable for removal of ingorganics from extracted groundwater, however, difficult to control for complex waste streams

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

Figure 2-3. Initial Screening of Technologies and Process Options (Cont.)

2.3 Evaluation and Selection of Representative Process Options

Technologies and process options that were determined to be both implementable and applicable for remediation of OU-1 were subjected to a more detailed evaluation in order to determine which process options would be used in the development of alternatives. The evaluation was based on a comparison of how each process option satisfied the given criteria relative to other process options under the same technology type and GRA.

2.3.1 Evaluation Criteria

The criteria used to evaluate process options were effectiveness, implementability, and cost. In accordance with the EPA RI/FS guidance (EPA 1988a), these criteria were not weighed equally, instead the effectiveness criteria held more importance than the implementability criteria, followed by the cost criteria. These criteria are described below in more detail.

Process options that were identified in the initial screening of technologies and process options were evaluated for effectiveness based on several factors. The primary factor was the extent to which an implemented process option would help achieve the RAOs for remediation of the Operable Unit. However, other factors included the potential effectiveness of the process option in handling the estimated areas or volumes of media; the potential impacts to human health and the environment during the construction and implementation phase; and the reliability of the process option as it relates to the contaminants and conditions at the site.

The implementability evaluation considered both the technical and administrative feasibility of implementing a given process option on site, relative to other process options in the same technology type. In this evaluation, however, the administrative implementability (i.e., institutional aspects such as availability of skilled labor, permitting requirements, and capacity and availability of treatment/storage/disposal facilities) weighed more heavily since the process options have already been screened on the basis of technical implementability.

The cost evaluation was based on engineering judgement and readily available information (i.e., EPA cost data and engineering analysis reports, Means data, engineering handbooks, recent symposiums, vendor supplied information, and EPA computer databases regarding Superfund Records of Decision [RODs] and cleanup actions). Costs were evaluated relative to other process options in the same grouping and were categorized qualitatively rather than quantitatively. Capital costs were separated from O&M costs to provide more detail and a High, Medium, Low ranking system was used for comparison. Options that were deemed significantly more expensive than others while providing similar levels of effectiveness were eliminated from further consideration, as well as options that had similar costs but were significantly less effective.

2.3.2 Evaluation of Process Options

The evaluation of process options presented in Figure 2-4 resulted in the selection of representative process options that were then combined to form a range of alternatives for remediation of OU-1 (see Section 3). Note that any of the process options that survived the initial screening, and are presented in Figure 2-4, could be incorporated into an established remedial action alternative in the future. However, in order to keep the number of alternatives limited and focused with regard to the RAOs and GRAs, representative process options were selected based on engineering judgement, balancing factors such as effectiveness, implementability, and cost.

2.3.3 Process Options Selected for Alternative Development

Due to the presence of an existing groundwater treatment system, the evaluation of process options was biased towards selection of the UV/peroxide treatment system for treatment of extracted groundwater. Since the system is proven to be effective in treating the contaminants present at OU-1, and the capital costs have already been incurred for this system, this process option is the most favorable for above-ground treatment of groundwater.

In addition, the limited availability of groundwater and the complex nature of the

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
No Action	None	Not applicable	May not achieve remedial action objectives although required for consideration by NCP	Difficult to implement if public concern is high regarding site conditions	Very Low Capital Very Low O & M
	Monitoring	Long-term groundwater monitoring	Effective in monitoring long-term site conditions, or with no action alternative as an inst. control	Readily implementable depending on remedial alternative selected	Low Capital Low O & M
		Short-term groundwater monitoring	Effective in monitoring short-term site conditions to protect worker and public health and safety	Readily implementable depending on remedial alternative selected	Low Capital Very Low O & M
Institutional Controls	Access Restrictions	Legal restrictions on access	Effective for relatively short-term control of present and future access to groundwater	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
		Fencing or other physical barriers	Moderately effective for relatively short-term control of present and future access to area	Readily implementable if area under consideration is already site property	Moderate Capital Low O & M
		Legal restrictions on land use	Effective for control of present and future use of land which is affected by remedial actions	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
Containment	Vertical Subsurface Flow Control	Subsurface Drains	Effective in diverting flow of groundwater around targeted areas to limit the mobility of contaminants	May be difficult to implement upgradient of plume due to proximity of buildings	Moderate Capital Low O & M
	Vapor Containment	Surface Cap	Effective in dispersing vapor plume and reducing localized atmospheric emissions	Readily implementable using common construction equipment	High Capital Moderate O & M
		Environmental Isolation Enclosure	Effective in preventing the inadvertent release of VOCs and dusts during remediation	Readily implementable with many vendors available as suppliers	Moderate Capital Low O & M
Removal	Passive Removal	Subsurface Drains	Effective in collecting ground water if the system is designed appropriately for site conditions	Modification of existing french drain would be readily implementable if required	Moderate Capital Very Low O & M
	Active Removal	Horizontal and/or Vertical Extraction Wells or Sumps	Effective in diverting, collecting, or recharging groundwater when gradient is relatively flat	Readily implementable based on existing site conditions if few wells are involved	Low Capital Low O & M
	Excavation	Loader/Excavator/Dozer	Tractor/wheel mounted vehicles commonly used to excavate or move large amounts of soil; can operate at various depths	Readily implementable although may be limited by bedrock formations	Low Capital Moderate O & M

Figure 2-4. Evaluation of Process Options

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
In-Situ Treatment of Chlorinated Solvents	Biological	Bioremediation	Effective in treating organics but difficult to monitor progress during in situ treatment; may result in residuals which require further treatment	Requires extensive treatability work to determine viability of microbial growth for existing site-specific conditions	Moderate Capital Moderate O & M
	Physical	Hot Air/Steam Stripping with Mechanical Mixing	Most effective in removing VOCs and SVOCs from groundwater but air/steam must be collected	Innovative technology which is considered moderately difficult to implement	High Capital High O & M
		Air Sparging	Effective in removing volatile organics and volatile inorganics from groundwater in situ	Requires horizontal drilling below water table so air will reach contaminant areas	Moderate Capital Moderate O & M
		Vapor Extraction	Moderately effective in removing VOCs from saturated soils although limited by nature of contamination	Would require the use of extraction wells to temporarily depress the water table	Low Capital Moderate O & M
		RF/Ohmic Heating	Effective in removing organics from ground-water but off-gas collection and treatment required	Treatability studies required to optimize frequency and phase settings for RFP	Moderate Capital Moderate O & M
Ex-Situ Treatment of Chlorinated Solvents	Biological	Bioremediation	Effective in treating organics but may possibly result in residuals which require further treatment	Readily implementable if all contaminants can be degraded under similar conditions	Moderate Capital Moderate O & M
	Chemical	Ultraviolet Photolysis with Chemical Oxidation	Effective and proven method of destroying organic contaminants in extracted groundwater	UV treatment system already exists on site and may be used w/o significant modification	High Capital High O & M
	Physical	Activated Carbon or Carbonaceous Adsorbents	Effective if used as a final polishing step in a groundwater treatment system	Readily implementable as this is a common technology supported by many vendors	Moderate Capital Moderate O & M
		Air Stripping	Effective in removing VOCs and some SVOCs from extracted groundwater in large volumes	Readily implementable as this is a common technology supported by many vendors	Low Capital Moderate O & M
		Hot Air/Steam Stripping	Effective in removing VOCs and some SVOCs from extracted groundwater	Readily implementable but more difficult than air stripping due to addition of steam	Moderate Capital Moderate O & M
	Thermal	Plasma Arc Discharge	Effective in destroying organics, including refractory halogenated compounds	Treatability studies required to optimize energy levels and treatment times for RFP	High Capital Moderate O & M
		Catalytic Oxidation	Effective in destroying organics, including refractory halogenated compounds	Treatability studies required to determine catalyst, temperature, and residence time	High Capital Moderate O & M

Figure 2-4. Evaluation of Process Options (Cont.)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
In-Situ Treatment of Inorganics	Pysical	Electrokinesis	Effective in removing ionic inorganic species from groundwater but unproven for most inorganics	Requires extensive treatability studies to determine applicability to site contaminants	Moderate Capital High O & M
Ex-Situ Treatment of Inorganics	Physical	TRU Clear (Proprietary Process)	Effective in removal of inorganic species from extracted groundwater to extremely low levels	Use of proprietary chemical available from single vendor may limit implementability	Moderate Capital Moderate O & M
		Oxidation/Reduction	Effective in precipitating many inorganics, however, is difficult to control for multiple species	Treatability studies required to determine reagents required for site contaminants	Low Capital Moderate O & M
		Ferrite Process	Effective in removal of metals and radionuclides from extracted groundwater by precipitation	Readily implementable using commonly available equipment and chemicals	Low Capital Moderate O & M
	Chemical	Ion Exchange	Effective in removing virtually all inorganics from water, however may require extensive pretreatment	Treatment system already exists on site and may be used w/o significant modification	Moderate Capital Low O & M
		Membrane Processes	Effective in removing many inorganics from water, however may require extensive pretreatment	Implementability may be limited by influent water quality and low COC concentrations	Moderate Capital High O & M
		Electrocoagulation	Effective in removing most inorganic ions from water, however, it is a nonselective process	Extensive treatability studies required due to innovative status of technology	Moderate Capital High O & M
		Precipitation	Effective in removing most inorganic ions from water, however, it is a nonselective process	Treatability studies required to determine chemicals which best address site conditions	Moderate Capital High O & M

Figure 2-4. Evaluation of Process Options (Cont.)

bedrock system beneath OU-1 favored treatment by process options that would seek to extract residual sources to the greatest extent possible while minimizing the potential for forcing contaminants further into the bedrock system. For this reason, process options such as bioremediation and soil flushing, which required injection of additional fluids into the subsurface were not viewed favorably. Instead, enhanced vapor extraction process options were selected for alternative development, and would be used in conjunction with limited groundwater pumping, to remove contaminated groundwater and potential residuals from the OU-1 subsurface.

Other options retained for alternative development were excavation and capping. These options were retained to provide conceptual variety to the alternatives presented for remediation of OU-1. Excavation could be used to remove subsurface soils to locate contaminated groundwater "pools" and to ensure that any residual sources are removed. Capping, on the other hand, would attempt to limit the mobility of vapor-phase contaminants, thereby miminimize the risk from one of the primary risk pathways, inhalation of groundwater volatiles.

These options were retained for development of remedial action alternatives at OU-1 and are further described in the discussion of alternatives presented in Section 3.0. Process options were also retained that would result in the assembly of limited or minimal action alternatives. These process options include long-term monitoring, use of the existing french drain system, and institutional controls. These options are also detailed in Section 3.O.

2.4 Existing IM/IRA Treatment System

The existing OU-1 Interim Measures/Interim Remedial Action (IM/IRA) water treatment system will provide a critical component for any proposed remedial action alternatives that require aboveground water treatment (see Figure 2-5). The system constitutes a comprehensive process treatment train for water contaminated with organic and inorganic (including radionuclide) contaminants. It consists of a collection and pumping system to supply the treatment facility, an influent storage and transfer system, separate treatment systems for

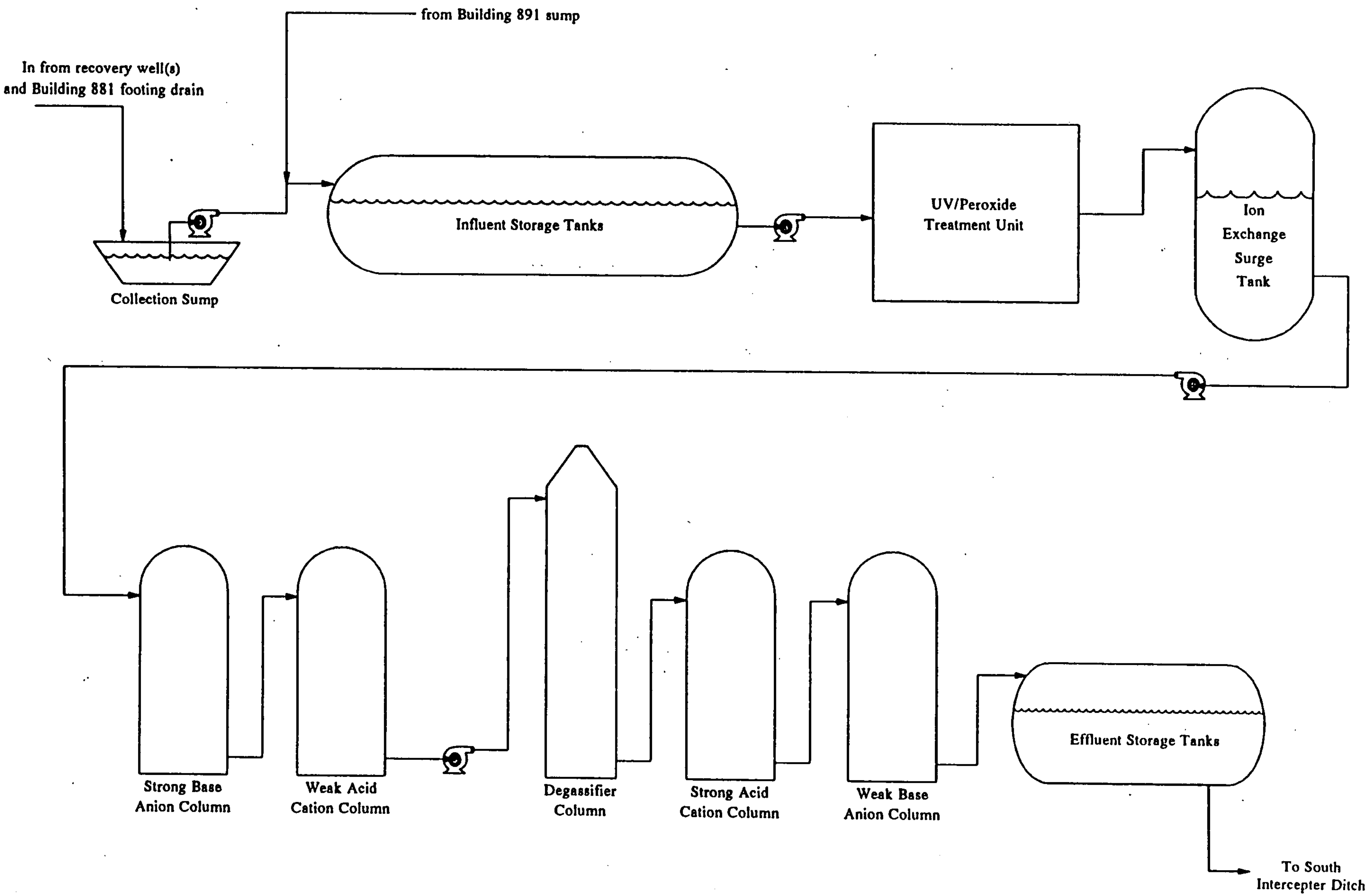


Figure 2-5. Summary View of Existing UV/Peroxide Treatment System

organic and inorganics contaminants, and an effluent storage and discharge system. The entire unit is designed for a 30 gpm flow rate capacity, with equalization tanks to normalize treatment rates.

The IM/IRA collection and pumping system includes the recovery well pump located in IHSS 119.1, two french drain sump pumps, and the Building 891 sump pumps (two). All of these pumps are controlled by level switches in the well or sump that determine whether the pumps operate. This collection system connects to the influent transfer system, which includes two influent equalization tanks and two influent transfer pumps. The influent transfer pumps supply water from the influent equalization tanks to an Ultraviolet/Hydrogen Peroxide (UV/H_2O_2) treatment unit at a constant rate. The UV/H_2O_2 unit is designed to destroy organic contaminants in the influent stream. Treatment efficiency depends on flow rate (residence time), H_2O_2 concentration, and UV wavelength intensity. The system has a design capacity of 30 gpm throughput, or 14,400 gallons per day using an 8-hour operating shift. It uses 50 mg/l of H_2O_2, with sixteen 15-kW UV lamps providing an equivalent power of 240 kW for breaking down organics.

Once it leaves the UV/H_2O_2 system, water enters the Ion Exchange System. This system consists of the ion exchange surge tank, four columns containing beds of ion exchange resins, and a degassing tower. Water from the UV/H_2O_2 system enters the ion exchange surge tank, from which water is pumped at a constant rate into the first ion exchange column. This column contains 28 cubic feet of Ionac A-440, a strong base anion resin for removal of uranium. From column 1, water goes directly to column 2, which contains 32 cubic feet of Ionac CC, a weak acid cation resin, for the removal of heavy metals. From this column, water enters the degassing tower to allow for the escape of carbon dioxide and other gases produced during the UV/H_2O_2 process. Excessive gas content in the ion exchange columns could cause short circuiting of the resins thereby reducing the efficiency of the system. After running through the degassing tower, water is then pumped to the third ion exchange column, which contains 56 cubic feet of Ionac C-240H, a strong acid resin for removing hardness and metals. From column 3 water goes to column 4, which contains 56 cubic feet of Ionac AFP-329, a weak base anion resin, for the removal of anions. Following the final ion exchange column, treated water is stored in one of three effluent storage tanks and discharged by gravity feed.

In terms of proposed remedial action alternatives, the system is capable of handling all of the contaminants identified in OU-1 groundwater and has sufficient capacity to handle proposed treatment rates. Additionally, treated effluent may be used to recharge OU-1 groundwater during remediation (if necessary).

3.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

This section discusses the process by which alternatives were assembled for remediating specific media or areas of OU-1. Included in this section is a summary of the screening of alternatives which resulted in a smaller, more manageable number of alternatives being retained for detailed analysis. In preparation of this technical memorandum, detailed information regarding the technical design of an alternative is not necessary; however, enough information is provided in this section to allow for a relative comparison of each alternative's effectiveness, implementability, and cost (i.e., screening of alternatives), and to provide the framework for future detailed analysis of each alternative (to be included in the final CMS/FS report). Where appropriate, figures have been included to clarify the alternative descriptions or to present conceptual designs for specific components of an alternative.

3.1 Development of Remedial Action Alternatives

Remedial action alternatives were developed by combining process options which were selected as being "representative" options based on the results of the evaluation of process options and technologies (see Section 2.0). Process options were combined in such a way as to permit alternatives to be developed that would range from treatment alternatives that eliminate or minimize the need for long-term management, to limited or no action alternatives. This range of alternatives includes containment options that involve little or no treatment, but achieve RAOs by preventing exposures or by reducing the mobility of contaminants. The no action alternative was developed to provide a baseline alternative against which other alternatives could be compared. In all cases the alternatives were developed with the goal of achieving the RAOs presented in Section 2.0 by combining appropriate GRAs to form site-specific remediation strategies.

As in the case of GRAs and RAOs, alternatives were developed on a medium-specific basis. Since the primary medium of concern being addressed by the OU-1 CMS/FS is groundwater, and since the source area at IHSS 119.1 contributes the largest portion of the risk at OU-1, alternatives were assembled to address groundwater contaminants both throughout OU-

1, and strictly within the vicinity of IHSS 119.1. The alternatives that were developed for remediation of OU-1 are the following:

- Alternative 0: No Action
- Alternative 1: Institutional Controls
- Alternative 2: Limited Action
- Alternative 3: Groundwater Removal by Pumping (OU-1)
- Alternative 4a: In Situ Treatment by RF/Ohmic Heating with SVE (IHSS 119.1 only)
- Alternative 4b: In Situ Treatment by RF/Ohmic Heating with SVE (OU-1)
- Alternative 5a: In Situ Treatment by Steam Injection with Mechanical Mixing (IHSS 119.1 only)
- Alternative 5b: In Situ Treatment by Steam Injection with Mechanical Mixing (OU-1)
- Alternative 6: Groundwater Removal by Soil Excavation and Sump Pumps (IHSS 119.1 only)
- Alternative 7: Containment by Capping w/Institutional Controls (IHSS 119.1 only)

Table 3-1 depicts a summary of the development of alternatives. The table presents the GRAs and process options that were combined to form the various alternatives. After developing alternatives for remediation of OU-1, the alternatives were screened on the basis of effectiveness, implementability, and cost. This screening is presented in the following subsections, and includes summary descriptions of each alternative as well as a final summary of the screening results. Alternatives that were dropped from further consideration are also indicated in Table 3-1 by shaded areas.

Table 3-1.
Summary of Groundwater Remedial Action Alternative Development[a]

GENERAL RESPONSE ACTION	PROCESS OPTION	PROPOSED REMEDIAL ACTION ALTERNATIVES				
		0	1	2	3	4a
		No Action	Institutional Controls	Limited Action	Groundwater Removal by Pumping	In Situ Treatment by RF/Ohmic Heating with SVE
APPLICABLE AREA =>		N/A	OU-1	OU-1	OU-1	IHSS 119.1 only
No Action	Not applicable	✓				
	Long-term monitoring	✓	✓	✓	✓	✓
Institutional Controls	Legal restrictions on land use		✓	✓		
	Legal restrictions on well placement		✓	✓		
Containment	Subsurface drains (existing French Drain)			✓	✓	✓
	Environmental isolation enclosure (optional)					
	Surface cap					
Removal	Subsurface drains (existing French Drain)			✓	✓	✓
	Horizontal and/or vertical extraction wells or sumps			✓	✓	✓
	Loader/dozer/excavator					
In situ treatment of chlorinated solvents	RF/ohmic heating					✓
	Hot air/steam stripping with mechanical mixing					
Ex situ treatment of chlorinated solvents	Ultraviolet photolysis with chemical oxidation			✓	✓	✓
Ex situ treatment of inorganics	Ion exchange			✓	✓	✓

[a]Shaded alternatives did not survive the screening process and are not subject to detailed analysis (see text).

Table 3-1 (Continued).
Summary of Groundwater Remedial Action Alternative Development[a]

GENERAL RESPONSE ACTION	PROCESS OPTION	PROPOSED REMEDIAL ACTION ALTERNATIVES				
		4b	5a	5b	6	7
		In Situ Treatment by RF/Ohmic Heating with SVE	In Situ Treatment by Steam Injection with Mechanical Mixing	In Situ Treatment by Steam Injection with Mechanical Mixing	Groundwater Removal by Soil Excavation and Sump Pumps	Containment by Capping w/Institutional Controls
APPLICABLE AREA =>		OU-1	IHSS 119.1 only	OU-1	IHSS 119.1 only	IHSS 119.1 only
No Action	Not applicable					
	Long-term monitoring	✓	✓	✓	✓	✓
Institutional Controls	Legal restrictions on land use					✓
	Legal restrictions on well placement					✓
Containment	Subsurface drains (existing French Drain)	✓	✓	✓	✓	✓
	Environmental isolation enclosure (optional)				✓	
	Surface cap					✓
Removal	Subsurface drains (existing French Drain)	✓	✓	✓	✓	✓
	Horizontal and/or vertical extraction wells or sumps	✓	✓	✓	✓	
	Loader/dozer/excavator				✓	
In situ treatment of chlorinated solvents	RF/ohmic heating	✓				
	Hot air/steam stripping with mechanical mixing		✓	✓		
Ex situ treatment of chlorinated solvents	Ultraviolet photolysis with chemical oxidation	✓	✓	✓	✓	✓
Ex situ treatment of inorganics	Ion exchange	✓	✓	✓	✓	✓

[a]Shaded alternatives did not survive the screening process and are not subject to detailed analysis (see text).

In order to support the screening of alternatives, information is included in each description which addresses the following:

- Size and configuration of on-site removal and treatment systems and containment designs
- Remediation time frames and treatment rates required to meet the RAOs
- Spatial requirements for constructing treatment or containment structures, or support facilities such as staging areas
- Packaging and transportation requirements for on- or off-site disposal options
- Permit requirements for off-site actions and discharges

3.2 Screening Criteria

Screening criteria are based on the EPA RI/FS (i.e., CERCLA) guidance, which states that alternatives should be screened prior to detailed analysis, by evaluating the short- and long-term aspects of each alternative's effectiveness, implementability, and cost. The primary focus of this evaluation is to "...ensure that the alternatives are being compared on an equivalent basis."

The effectiveness evaluation of each alternative is based on the alternative's ability to protect human health and the environment and to reduce the toxicity, mobility, or volume of the hazardous constituents present. This evaluation considers the short-term impacts associated with the construction and implementation period of the alternative, as well as the long-term effectiveness of the alternative after remedial action is completed.

The implementability evaluation of each alternative focuses on both the technical and administrative feasibility of constructing, operating, and maintaining the remedial action alternative. In this case, the technical feasibility of an alternative refers to its ability to be readily constructed and operated, to meet the required RAOs, and to meet any appropriate governing regulations during operation. Maintenance, replacement, and monitoring of technical components of the alternative are also considered in this evaluation. The administrative feasibility of an alternative is evaluated by examining the alternative's requirements for permits and approvals from regulating agencies for treatment, storage, and/or disposal services, and for specialized equipment and labor.

Cost estimates are normally not accomplished at this stage of alternative development. Therefore, the focus of the cost evaluation, at this point, is to make comparative estimates amongst alternatives by maintaining relative accuracy across the various alternatives. True cost estimates are used in the detailed analysis and should quantify the relative comparisons performed during this screening. Cost information at this stage is based on readily available information such as databases, cost curves, vendor information, and/or generic unit cost guides. Both capital and operation and maintenance (O&M) costs are considered, with engineering judgement playing a large role in the evaluation. Detailed costs associated with each alternative which survives the screening process will be included in the final CMS/FS report.

3.3 Groundwater Remedial Action Alternatives

Groundwater remedial action alternatives were developed that could potentially achieve the RAOs described in Section 2.0. The primary risk pathways that determined which GRAs would be used to develop alternatives were based on the OU-1 BRA, which indicated that inhalation of vapors rising up through unsaturated soils and ingestion of groundwater itself were the largest concerns. The following groundwater alternatives were designed to achieve RAOs by removing and destroying the contaminants in groundwater, by restricting access to wells positioned within the boundaries of OU-1, and/or by limiting access to the site completely. These alternatives assume that surface soil hotspots would be removed prior to commencing remedial activities, and would be put into temporary storage for treatment with another OU or shipped off site for immediate treatment and/or disposal. Because OU-2 will address the low-level plutonium surface soil contamination in OU-1, this OU will most likely also assume responsibility for the hotspots excavated from OU-1.

3.3.1 Alternative 0: No Action

The No Action alternative for groundwater was developed to meet the requirements of the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) (section 300.430(e)(g)) which state that a No Action alternative should be developed regardless of site-specific conditions (EPA 1990). The alternative will provide a baseline against which other alternatives can be compared during the detailed analysis of alternatives. The No Action alternative uses the results of the BRA to define what the exposure levels would be to receptors under this alternative.

This alternative includes long-term monitoring only to determine if any changes occur in contaminant concentrations or in contaminant migration patterns. Long-term monitoring of groundwater would begin immediately as an extension of existing efforts, and would take place for as long as institutional controls are active at the site, or until it is determined that monitoring is no longer required. The monitoring program required would be similar to existing programs and would not require installation of additional wells.

This alternative assumes that the site would eventually be abandoned, and that no remedial actions would be initiated to reduce the risk from groundwater contaminants. The alternative assumes that the treatment portion of the existing french drain system would be non-operational, although the drain would continue to passively collect groundwater and divert its flow.

Since no remedial actions would be conducted under this alternative, there is no remediation time frame involved. This alternative would also not involve any packaging or transportation of waste, nor any permitting actions. This alternative does not require a screening evaluation since it must be carried through detailed analysis regardless of its effectiveness, implementability, or cost.

3.3.2 Alternative 1: Institutional Controls

This alternative is intended to minimize the risk from contaminated groundwater by restricting access to any wells impacted by OU-1 contaminants, and by eliminating the possibility of building construction above areas known to be contaminated with VOCs. The alternative assumes that the existing french drain system would not be operational as in the No Action alternative.

Long-term monitoring would be required for this alternative to determine when institutional controls could be discontinued. Once acceptable groundwater contaminant concentrations were achieved through natural degradation and dispersion of contaminants, the area would be released from institutional controls. Long-term monitoring would take place for as long as required to meet this criterion. The monitoring program required would be similar to existing programs and would not require installation of additional wells.

This alternative assumes that the site would not be abandoned during the institutional control period, but that no remedial actions would be taken to actively reduce the contaminant concentrations in groundwater. As in the No Action alternative, there is no remediation time frame with this alternative since the site would not be released until acceptable groundwater concentrations are achieved. However, for the purposes of detailed analysis, a 30-year institutional control period will be assumed for long-term monitoring.

This alternative would not involve any packaging or transportation of waste, nor any permitting actions, other than the administrative requirements associated with maintaining the site secure.

Effectiveness Evaluation - This alternative would effectively protect human health and the environment from impacts associated with OU-1 contaminants. By limiting access to the OU-1 area and eliminating the potential for either building construction or well installation at the site, both human and ecological receptors would be protected from either ingesting contaminants directly, inhaling volatilized contaminants, or coming into dermal contact with contaminants. Overall, however, this alternative would not reduce the toxicity, mobility, or volume of contaminants at the site. Eventually natural processes would reduce contaminant concentrations at OU-1, however, the rate of dispersion and/or degradation would be slow compared to alternatives which utilize active remediation measures.

This alternative would be effective for as long as institutional controls were in effect. For the purposes of detailed analysis, it is assumed that institutional controls would be active for at least 30 years. Institutional controls would be terminated once contaminant concentrations reached acceptable levels; therefore, this alternative would be effective for both short-term and long-term protection.

Implementability Evaluation - This alternative would be readily implementable. The alternative does not require construction of any new facilities and relies solely on administrative controls to avoid exposure to OU-1 contaminants. Existing fencing and site checkpoints provide physical barriers to access, while administrative deed and permit restraints would prevent any future unauthorized use of the site. These restraints would be readily implementable and would not result in any substantial changes to existing site conditions. Shutting down the existing IM/IRA system would likewise be a relatively simple operation, although the treatment portion of the unit might still be operated for the benefit of other operable units.

Cost Evaluation - The primary cost component of this alternative is the long-term monitoring that would be required to determine when acceptable contaminant concentrations have been achieved. As previously stated, for the purposes of detailed analysis it is assumed that this period would last at least 30 years. It is expected that contaminant concentrations in IHSS 119.1 would not reach acceptable levels within this time period, however, and would result in an institutional control period that lasted much longer.

3.3.3 Alternative 2: Limited Action

This alternative is intended to minimize the risk from contaminated groundwater by restricting access to any wells impacted by OU-1 contaminants, while continuing to treat groundwater collected by the existing IM/IRA french drain system. This alternative is very similar to Alternative 1 with the exception that the IM/IRA system would not be shut down.

Long-term monitoring would take place for as long as required to verify that contaminant concentrations in groundwater have been permanently reduced below appropriate limits. The monitoring program required would be similar to existing programs and would not require installation of new wells. For this alternative, the existing extraction well located in IHSS 119.1 would continue to be used as a groundwater collection source.

Although remedial actions would be conducted under this alternative in the form of the french drain, there is no remediation time frame defined since the system is currently operational and would continue operating until acceptable contaminant concentrations are achieved. Based on operations to date of the french drain system, however, it is reasonable to assume that its slow groundwater collection rate would require its operation for an extensive period of time. Long-term monitoring of groundwater would also begin immediately as an extension of existing efforts. This alternative could involve packaging and transportation of spent ion exchange resin.

Effectiveness Evaluation - The effectiveness of this alternative is similar to that of Alternative 1 in terms of protectiveness, although this alternative would reduce the toxicity, mobility, and volume of contaminants at the site by continuing to treat groundwater collected by the french drain and the existing UV/peroxide treatment system. The overall reduction in toxicity, mobility, and volume of contaminants, however, is minimal compared to the extent of contamination present at OU-1.

According to the *System Operation and Optimization Test Report* for the OU-1 IM/IRA, of the four contaminants present in groundwater that contribute the largest risk to a human receptor, only tetrachloroethene was consistently detected in samples taken from the system influent between the months of March and September 1992. Carbon tetrachloride was never detected, and both 1,1-dichloroethene and 1,1,1-trichloroethane resulted in only one detection each out of 13 samples taken. The concentrations of the contaminants that were detected were several orders of magnitude below IHSS 119.1 concentrations and were within half an order of magnitude of Federal Maximum Contaminant Levels (MCLs). This data suggests that this alternative would not provide an effectiveness in protecting human health or the environment much greater than institutional controls with no active treatment applied.

Particularly in light of the fact that the effluent storage tanks used for the treatment system may be contributing to the contaminant concentrations in the treated water.

Implementability Evaluation - This alternative would be readily implementable. The alternative does not require construction of any new facilities as is the case with Alternative 1. Existing fencing and site checkpoints provide physical barriers to access, while administrative deed and permit restraints would prevent any future unauthorized use of the site. The IM/IRA treatment system has already been constructed and is available for use at OU-1. During operation, none of these systems would exceed government regulations (by design) for emissions of either vapor-phase or aqueous-phase contaminants. Spent ion-exchange resins would be sent to an approved disposal or recycling facility and would not cause administrative difficulties.

Cost Evaluation - The primary cost component associated with this alternative involves the continued operation of the existing IM/IRA treatment system. Its operation along with long-term monitoring would make O&M costs the primary cost driver for this alternative. As in Alternative 1, for the purposes of detailed analysis it is assumed that the institutional control period would last at least 30 years. Long-term monitoring costs would be slightly higher for this alternative than Alternative 1 due to the additional sampling required for the UV/peroxide treatment system effluent.

3.3.4 Alternative 3: Groundwater Removal by Pumping (OU-1)

Alternative 3 presents a standard pump and treat approach to groundwater removal and treatment at OU-1. The operation of a series of extraction wells in each area containing aqueous phase contaminants would provide for recovery of the contaminated groundwater, while the existing IM/IRA treatment system would facilitate contaminant destruction. This alternative would seek to provide protection of human health and the environment by removing contaminants from OU-1 groundwater. The institutional control of long-term groundwater monitoring would be employed to verify that contaminant concentrations remain below PRGs after the treatment portion of this alternative is complete. The existing french drain would provide containment of contaminants during remedial actions while also assisting in the collection of groundwater. After remedial actions are completed, however, the treatment system would be shut down and dismantled, unless other operable units required its use.

Extraction of contaminated groundwater at IHSS 119.1 would be accomplished by installing two to four extraction wells in addition to the existing extraction/recovery well. Two injection wells would also be installed above IHSS 119.1 to assist the extraction wells. Removal of the contaminated groundwater in the area south of Building 881 would be accomplished by installing three to five extraction wells south of Building 881 and north of the french drain. Two to three injection wells would be installed upgradient to the areas of highest groundwater concentration. The area south of IHSS 119.2 would require installation of an estimated 6 to 10 extraction wells. Four to six injection wells would be installed upgradient and on either side of the contaminated area. Both the extraction wells and injection wells in all three areas would be 4-inch wells with a projected radius of influence of 25 feet. Because of the low hydraulic conductivity and small saturated thickness of 881 Hillside colluvial materials, cyclical operation with pumping rates below 5 gal/min. would be required to remove groundwater without desaturating the well cells.

Groundwater recovered from the extraction wells would be routed to the french drain sump, then transferred to the influent storage tanks of the existing IM/IRA treatment system. Recovered groundwater would therefore have to be pumped at a flow rate compatible with the system's 30 gpm capacity. A tap from the effluent tank would be used to route treated groundwater to each injection well to provide for groundwater recharge at each location. This system was constructed to treat groundwater from the 881 Hillside area to achieve the treatment goals presented in the *Systems Operation and Optimization Test Report* (DOE 1992). A flow diagram of this water treatment system is presented in Figure 2-5.

Effectiveness Evaluation - Sporadic groundwater contaminant concentrations and seasonal groundwater volumes at OU-1 limit the overall effectiveness of this alternative. Although the treatment system is proven to be effective in removing OU-1 contaminants, the effectiveness of the extraction process would be poor because of the OU-1 hydrogeology and the tendency of pump and treat systems to require extended remediation time frames to reduce the concentration of residual contamination.

Computer simulations of domestic water production capabilities from OU-1 were completed and presented in the report entitled *OU-1 Domestic Water Supply Simulations* (EG&G 1992). Results of these simulations showed that with a hydraulic conductivity of 1E-4 cm/sec, pumping rates exceeding 0.14 gpm would desaturate the well cell in under 365 days. The model assumed a 12-hour pumping period. With a hydraulic conductivity of 1E-5 cm/sec, pumping rates exceeding 0.013 gpm would desaturate the well cell in under 365 days. Based on the RI report, the hydraulic conductivity at IHSS 119.1 and the area south of IHSS 119.2 is estimated at 9.4 X 10^{-5} ft/min (4.8 X 10^{-5} cm/sec), while the area south of Building 881 has an estimated hydraulic conductivity of 1.5 X 10^{-5} ft/min. (7.6 X 10^{-6} cm/sec.). These hydraulic conductivities would require extremely low pumping rates to remove contaminated groundwater without desaturating the well cells.

The overall remediation time frame based on using this alternative would be extensive considering the low groundwater pumping rates achievable at OU-1. The potential exists for an extensive extraction time required for removal of residuals potentially present in saturated soils.

Implementability Evaluation - This alternative would be readily implementable if it was selected as the preferred remedial action alternative. The equipment required for the alternative is commonly available and does not require any specialized construction and/or operation personnel. Injection/extraction wells are widely used and equipment could be obtained from a number of suppliers. The IM/IRA treatment system has already been constructed and is available for use at OU-1. During operation, none of these systems would exceed government regulations (by design) for emissions of either vapor-phase or aqueous-phase contaminants. Spent ion-exchange resins would be sent to an approved disposal or recycling facility and would not cause administrative difficulties. Administratively, installation of groundwater extraction wells would require well installation permits, but such permits are readily obtainable. Off-gas treatment would require an air treatment permit, but there is no foreseeable difficulty in obtaining such a permit.

Cost Evaluation - The capital cost requirements for this alternative are relatively low as a fairly small number of injection/extraction wells would be required and the IM/IRA treatment system has already been constructed. O&M costs would be quite high for this alternative compared to other alternatives considered due to the extensive time frame required for groundwater extraction and the high O&M costs associated with powering the UV lamps used in the IM/IRA treatment system.

3.3.5 Alternative 4a: In Situ Treatment by RF/Ohmic Heating with SVE (IHSS 119.1 only)

This alternative seeks to enhance the vaporization and subsequent recovery through vapor extraction of contaminants present in the saturated soils and groundwater at OU-1. Such a technology would target contaminants that have partitioned to the aqueous phase in the subsurface or have adsorbed onto subsurface soils. This alternative considers technologies that enhance vaporization through the elevation of subsurface temperature in areas where target contaminants are concentrated. Groundwater residing in shallow pools throughout IHSS 119.1 would be extracted via existing wells, the existing French Drain, and 1 to 2 new recovery wells. Collected groundwater would be treated by the existing IM/IRA treatment system. These same areas would be subjected to vaporization enhancement techniques once desaturated to enhance the removal of any residual contaminants.

As soil gas contaminated with contaminant vapors is recovered through a standard vapor extraction system and replaced with clean soil gas, aqueous phase and adsorbed contaminants must reach a new equilibrium (with the clean soil gas); thus, increasing the vaporization rate of these contaminants which, subsequently, would be available for recovery by vapor extraction. Although this shift in equilibrium would increase the effectiveness of the vapor extraction system, the primary increase in total contaminant recovery would result from an increase in the number of open pore spaces available for vapor transport. Any vaporization enhancement techniques used with vapor extraction would decrease the moisture content of the surrounding media. Pore spaces that were initially filled with water would be opened once the water was vaporized and driven off. The open pore spaces would allow for a greater diffusion rate of vapor phase contaminants, thereby increasing their extraction rate and possibly the radius of influence of a vapor extraction system.

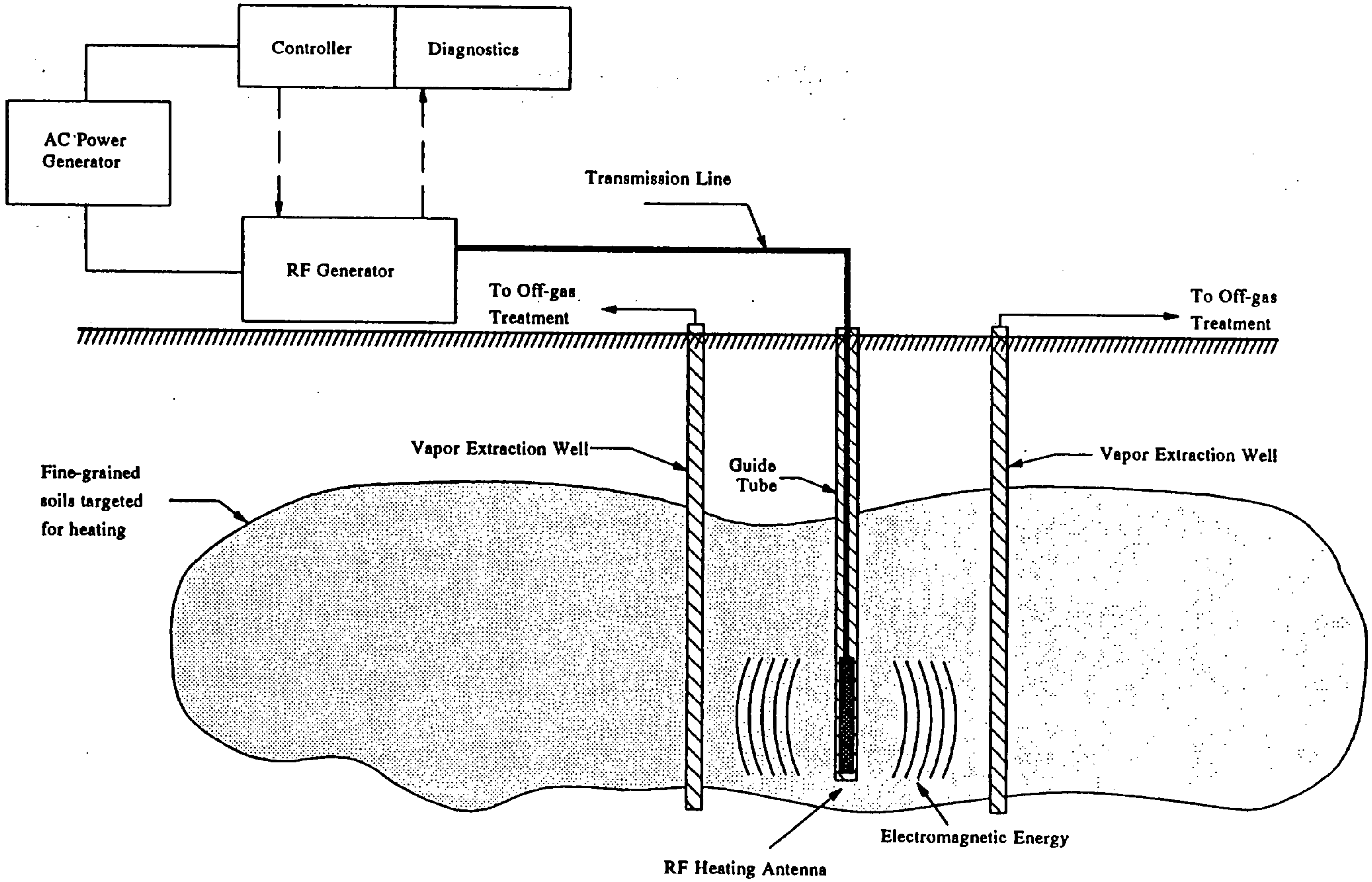
By enhancing the vaporization of target contaminants in various regions of the subsurface, the performance of a vapor extraction system would likely increase with regard to overall contaminant recovery. This alternative considers two viable treatment technologies that can effect an increase in subsurface soil temperatures — radio frequency heating and electrical resistance (ohmic) heating.

Radio Frequency Heating

Radio frequency (RF) heating was selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU-1 that are contaminated with those contaminants that are VOCs. RF heating is an innovative in-situ technology for volatilizing organic constituents in soil and water as well as vaporizing pore space moisture. The technology is desirable since additional chemicals are not introduced into the subsurface and no special arrangement (e.g., grids) are necessary as in conventional electrical resistance heating.

The in-situ RF heating process requires minimal intrusion, using 3- to 6-inch diameter boreholes containing strategically placed antennae in the desired treatment area. Through a combined mechanism of ohmic and dielectric heating, the temperature in the media is raised and the volatile and semivolatile organic constituents are volatilized (Kasevich 1992). Volatilized organics are then collected with the vapor extraction system and subjected to further treatment. RF heating is expected to supplement vapor extraction in a manner that allows for quicker recovery of VOCs from certain areas of the subsurface. Specifically, heating "hotspots" can expedite VOC recovery in the vapor form (i.e., hotspots are likely to contain aqueous phase and adsorbed VOCs which would be driven to vapor under elevated temperature conditions). Figure 3-1 illustrates a simple application of RF heating combined with vapor extraction for this alternative.

The dielectric loss of a material (i.e., the amount of energy a material dissipates as



Note: Figure represents information provided in part by KAI Technologies, Inc.

Figure 3-1. Conceptual View of Radio Frequency Heating System heat when placed in a varying electric field) contributes to the heating of the contaminated media. Since the primary mechanism of RF heating is not thermal conduction but rather electromagnetic radiation (in the radio frequency range), thermal conductivity and hydraulic conductivity of the media are not the primary factors affecting heating performance. An indicator of a material's ability to successfully absorb electromagnetic energy is its dielectric constant. Most soils have suitable dielectric constants that allow for effective treatment. Water and/or soil moisture is vaporized by RF energy; however, steam is transparent to RF energy and does not continue to absorb radiation energy. While the steam may become superheated, this occurs only by energy conduction from the solid media and not from direct electromagnetic energy absorption. The steam in turn serves to heat surrounding materials, enhancing additional vaporization. Thus, water and/or soil moisture does not present a hindrance to the treatment process. Fractures and voids within the contaminated matrix also do not present treatment problems since thermal conduction is not the primary heat transfer mechanism. Densely packed soils are well suited to this treatment as are other consolidated geologic materials. A variety of heating profiles can be generated by manipulating the subsurface placement of RF antennae, their operating frequencies, and the phase output of the different antennae. Virtually uniform heating within a specified volume can be achieved with minimal heating of surrounding material using a properly designed configuration. Thus, localized treatment can be attained with proper design.

RF heating has been shown to be capable of increasing soil temperature to approximately 500°F. This temperature would be great enough to volatilize both sorbed and potentially dissolved phase contaminants (e.g., aqueous phase) in the subsurface materials as well as drive off any moisture in nearby pore spaces. The temperature of the subsurface medium would be raised gradually; therefore, vapor extraction wells would be able to extract vapor as it is generated. The heating and resulting steam/vapor generation rate could be controlled so that the capacity of the vapor recovery system would not be exceeded. Such control would prevent the spread of contamination by steam plume expansion. Also, RF heating would only be implemented in the vicinity of a vapor extraction well. Placement of an RF heating antennae in this manner would provide assurance that RF heating would not lead to a spread of contamination. A vapor recovery system supplemented with RF heating would likely require additional air drying capacity, depending on the off-gas treatment utilized, since it is expected that the RF heating system would lead to the extraction of a greater amount of soil moisture than conventional vapor extraction.

The primary piece of equipment of this alternative is the applicator antenna, which is placed in a borehole. This antenna is generally a flexible component of varying length that radiates electromagnetic energy in the form of radio frequency waves. The energy originates from a generator at the surface and is transmitted to the antenna via a metal coaxial cable. Standard drilling equipment can be used to complete a borehole. The borehole is generally cased with fiberglass or a similar material that is transparent to electromagnetic radiation. The antenna can be placed in vertical or horizontal boreholes. Also, several antennae may be used concurrently in various areas with elevated contaminant concentrations.

Locations of RF antennae and vapor extraction wells for cleanup of the volatile subsurface contaminants at OU-1 are contingent on detailed design through which the optimum system design would be defined; however, it was assumed under this alternative that one RF heating borehole would be installed to a depth of 10 to 20 feet for each vapor extraction well location. The number of vapor extraction wells required would range from 5 to 10 depending on saturation levels. The spacing between multiple boreholes can range depending on the RF heating frequency, depth interval of heated volume, and properties of the materials heated. An array of multiple boreholes can provide uniform heating of a given subsurface volume. Control devices monitor performance of the RF generator and adjust the outputs to optimize system performance. Soil gas monitoring wells must be in place in the vicinity of the RF heating antennae. These wells are necessary to monitor for potential increased migration of contaminant outside of the radius of influence of the vapor extraction well(s).

Support equipment for RF heating can be housed in one trailer. A portable power supply, such as a diesel motor generator, may provide the necessary three-phase power for the RF antennae. All transmission lines connecting support equipment to the RF antennae are commercially available. There are no special permits required for operation of an RF heating system, other than those required for air emissions.

Electrical Resistance Heating

Electrical resistance heating was also selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU-1 that are contaminated with volatile contaminants. Like RF heating, electrical resistance heating is an innovative in-situ technology for enhancing the performance of soil vapor extraction by volatilizing organic constituents in soils and groundwater, and by vaporizing pore space moisture. Unlike RF heating, however, electrical resistance heating results from the transmission of an electrical current through the media targeted for cleanup. As such, a prerequisite for electrical resistance heating is that the media must be able to conduct an electrical current. Electrical resistance heating requires the placement of a grid of electrodes and sometimes the addition of water in the area targeted for remediation. The process requires only minimal intrusion and has most often been implemented using six electrodes installed in a hexagonal pattern to the depth of the contaminants, with a vapor extraction well placed in the center of the pattern as shown in Figure 3-2 (Aines et al).

Six- or three-phase power can be used to supply current to the installed electrodes. There is some benefit with six-phase power in that a more uniform heating pattern can be realized in the area being treated (Buettner et al). However, the increased uniformity comes at the expense of needing additional equipment to split normal three-phase power into six-phase. Electrodes are usually constructed of stainless steel tubing, which can also serve as passive air inlets.

The principle of electrical resistance heating is simple. Basically, electrical currents are made to flow between electrodes placed in a contaminated region causing resistance heating (much the same way that passing an electrical current through an oven heating element generates resistance heating). Current flow through subsurface materials tends to be greatest in fine-grained soils such as silts and clays. These types of soils are generally less permeable than sands and gravel; thus, heating the clays and silts can drive off contaminants contained therein that are not easily accessible with conventional soil vapor extraction. Once the volatile contaminants are driven out of the less permeable clays and silts into the more permeable sands

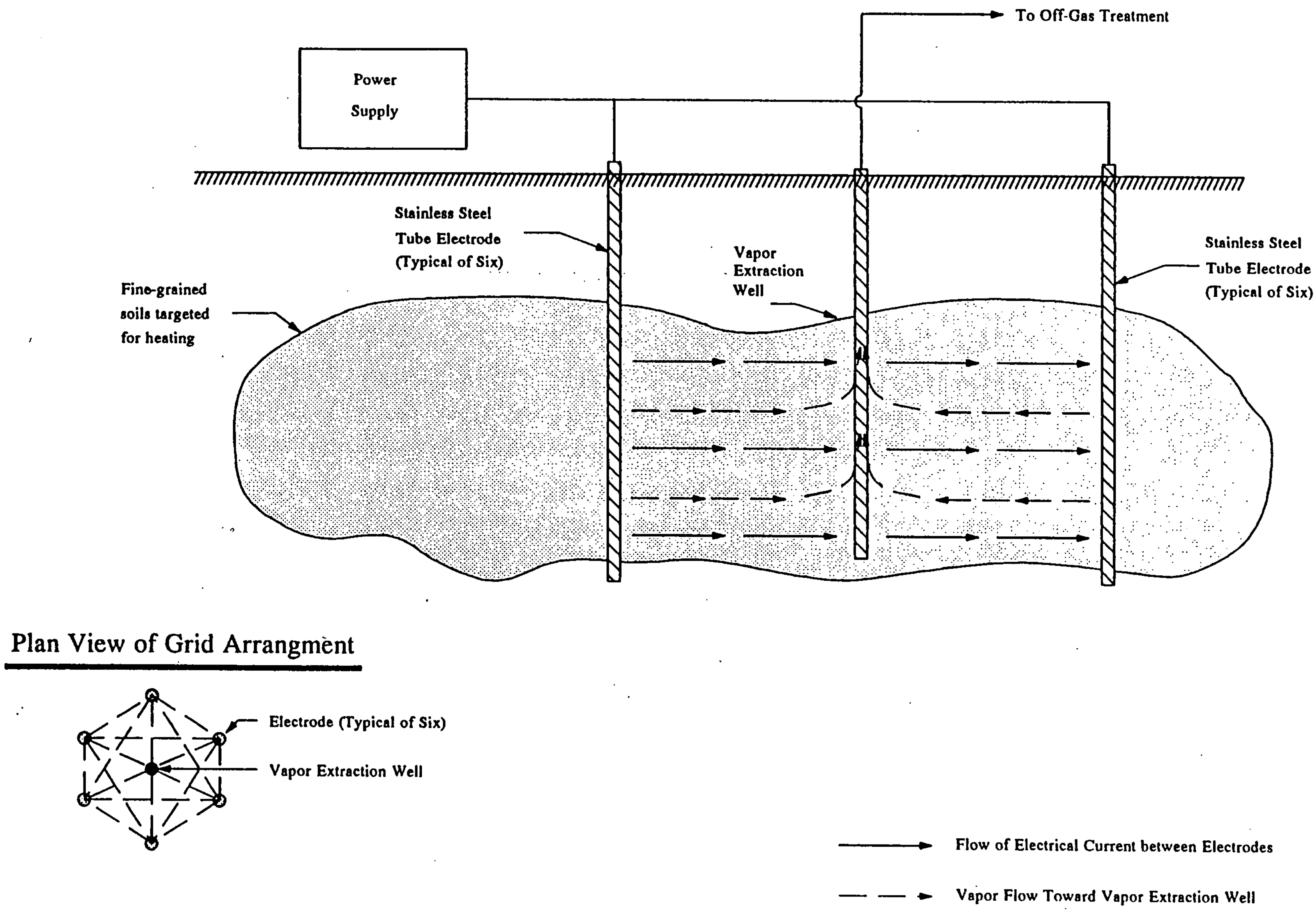


Figure 3-2. Conceptual View of Electrical Resistance Heating System

and gravel, they are more susceptible to recovery by vapor extraction. As with RF heating, soil moisture can be heated with electrical resistance heating to generate steam. Steam can provide additional stripping of adsorbed contaminants. Also, the removal of soil moisture can increase the air flow permeability of the soil being treated, thus enhancing the capability of vapor extraction to remove contaminants (but lessening the ability to continue heating the subsurface with electrical current).

The primary pieces of equipment needed to support electrical resistance heating include stainless steel piping (for electrodes), a 60 Hz power supply, an optional six-phase transformer, thermocouples for monitoring subsurface temperature, and a vapor recovery/treatment system. Electrode grids may be placed at various locations targeted for treatment. Extracted vapors from multiple locations may be directed to a central treatment location or to individual treatment units.

The location of the electrode grid(s) and vapor extraction well(s) for cleanup of the volatile subsurface contaminants at OU-1 are contingent on treatability test results in which the optimum system design would be defined; however, for this alternative it was assumed that one grid would be installed at IHSS 119.1. This grid would have six electrodes inserted to approximately 20 feet below the surface in a hexagonal arrangement making up a circle with a diameter of approximately 20 feet. Additional grids would be required to remediate the entire site.

Effectiveness Evaluation — The critical factor for RF heating effectiveness is the dielectric constant of the media. The soils that comprise OU-1 are expected to be amenable to absorption of RF energy, resulting in effective contaminant and soil moisture vaporization. Only volatile substances would be mobilized, and additional waste disposal problems that may be caused by excavation of the shallow alluvial materials would be avoided through this alternative. Extracted groundwater would be treated by the existing IM/IRA treatment system which would effectively remove or destroy any OU-1 contaminants.

A critical factor in the effectiveness of electrical resistance heating is the ability of the media being treated to conduct an electrical current between electrodes of the grid. Fine-grained soil layers at OU-1 containing contaminated soil moisture are above fractured bedrock. These fine-grained layers should be capable of conducting an electrical current; however, the ability to maintain an elevated temperature in these soils over time may decrease as soil moisture is driven off. Heating of these subsurface soils will make volatile contaminants susceptible to recovery by a vapor extraction well. Extracted groundwater would be treated by the existing IM/IRA treatment system which would effectively remove or destroy any OU-1 contaminants.

Potential impacts to human health and the environment would occur through releases of recovered soil vapors at the ground surface or within the collection and treatment facility. Installation of a borehole(s) and vapor extraction well(s) in and around IHSSs poses a potential risk as "hotspots" may be disturbed. Existing drilling protocols would be used to minimize worker exposure. Overall, operation of an RF heating system combined with vapor extraction would not be expected to pose direct adverse impacts given implementation of standard health and safety measures. For the electrical resistance heating, there is a danger to workers of electrical shock in the vicinity of the electrical resistance heating grid. As such, strict control of worker access must be administered during electrical heating operations. Overall, the operation of an electrical resistance heating system combined with vapor extraction would not be expected to pose direct adverse impacts given implementation of standard health and safety measures.

Implementability Evaluation — A potential technical constraint for RF heating is that the equipment necessary is relatively specialized; however, the equipment is readily available through several technology vendors. No significant administrative constraints would be expected to construct and operate an RF heating system since it requires no introduction of substances to the site and requires minimal subsurface intrusion. A potential technical constraint for electrical resistance heating is that the equipment necessary is relatively specialized; however, the equipment is readily available through several technology vendors. No significant administrative constraints would be expected to construct and operate an electrical resistance heating system since it requires no introduction of substances to the site and requires minimal subsurface intrusion.

Permit requirements must be met for discharge from an off-gas treatment system. Well installation permits would also be needed for any wells installed at OU-1. Treatability testing would be required and would include bench-scale tests to determine optimum operating parameters for RF heating or electrical resistance heating, and a pilot-scale test to determine optimum locations for applying RF heating antennae or electrical resistance heating electrodes, as well as site-specific performance.

Cost Evaluation — There is a moderate level of capital cost associated with RF heating. Much of the capital cost is dependent on the number of applicator antennae installed and independent power/control trailers needed. O&M costs are also highly dependent on site conditions but are expected to be high relative to an alternative that includes only conventional vapor extraction. The cost of power to operate the RF heating system and monitoring during remedial activities are key contributors to the O&M costs. Actual cost figures for the use of RF heating would be clearly defined in the detailed analysis of alternatives; although, at this stage there appears to be no cost factors that would eliminate consideration of RF heating to supplement a conventional vapor extraction program at OU-1.

There is a moderate to high level of capital cost associated with electrical resistance heating. Much of the capital cost is dependent on the number of grids and power control systems that would be utilized at OU-1. O&M costs are also highly dependent on site conditions, but are expected to be high relative to an alternative that would include only conventional vapor extraction. The cost of power to operate an electrical resistance heating system and monitoring during remedial activities are key contributors to the O&M costs. Actual cost figures for the use of electrical resistance heating would be more clearly defined during detailed analysis; although, at this stage there appears to be no cost factors that would eliminate consideration of electrical resistance heating to supplement a conventional vapor extraction program at OU-1.

3.3.6 Alternative 4b: In Situ Treatment by RF/Ohmic Heating with SVE (OU-1)

This alternative is identical to Alternative 4a with the exception that it would be implemented across all of OU-1, rather than just at the IHSS 119.1 source location. This alternative would therefore require a larger number of groundwater and soil vapor extraction wells and RF antennae or electrical grids, depending on the specific process option selected for remediation. The technical description for this alternative is included under Alternative 4a.

Effectiveness Evaluation —. This alternative would be effective in reducing contaminant concentrations across the OU-1 site. The effectiveness of RF/Ohmic heating is described in detail under Alternative 4a, however the OU-wide alternative would be slightly more effective in reducing overall contaminant concentrations. The alternative may present a slightly greater risk to workers than Alternative 4a due to the added power requirements and well installations, however both of these factors would be controlled by appropriate site safety measures.

In terms of reduction of toxicity, mobility, or volume, this alternative would achieve a greater reduction in all three of these areas than Alternative 4a due to the larger extent of the cleanup under this alternative.

Implementability Evaluation — The implementability of this alternative is discussed in detail under Alternative 4a. This alternative may be slightly more difficult to implement due to the added equipment required to scale up the system described in Alternative 4a. In addition, a greater number of personnel would be required to implement this alternative than Alternative 4a although the difference would not be substantial.

Cost Evaluation — This alternative would cost much more than Alternative 4a because of the greater power requirement associated with treating the entire operable unit, thus higher O&M costs. This would be particularly true with electrical resistance heating which has a smaller treatment area than a single RF antennae. Capital costs would be also be greater although this cost difference would not be as dramatic as the increased O&M costs. On an OU-wide basis several RF antennae could be operated at different locations and cycled to other locations during remediation. Likewise, a few electrical resistance heating grids could be implemented at several locations throughout the operable unit.

3.3.7 Alternative 5a: In Situ Treatment by Steam Injection with Mechanical Mixing (IHSS 119.1 only)

This alternative would use groundwater extraction and steam enhanced vapor extraction with mechanical mixing to enhance recovery of contaminants present in the subsurface at IHSS 119.1. Such a technology would target contaminants that have partitioned to the aqueous phase in the subsurface or have adsorbed onto the subsurface soils. This alternative considers a technology that enhances vaporization and recovery through elevation of subsurface temperature by steam and hot air injection and mechanical mixing in areas where the target contaminants are concentrated.

This alternative requires the remediation of approximately 15,000 cubic yards of soil in IHSS 119.1 by in-situ treatment with a mobile treatment system. The treatment system selected would use steam and hot air to enhance volatilization of adsorbed and dissolved VOCs while simultaneously increasing contact of the steam/hot air with the VOCs by mechanical mixing. (Available groundwater would be extracted prior to the steam treatment.) Steam is the primary means of temperature elevation induction, while hot air is supplied to increase subsurface vapor flow and recovery. The mixing enhances volatilization by increasing desorption surface area and eliminating barriers to contact between the contaminants and the steam/hot air.

The primary treatment system in this alternative consists of a caterpillar mounted drill rig with specialized drilling equipment. The drill equipment is capable of delivering multiple treatment reagents, such as hot air and steam, simultaneously via piping in a hollow drill bit shaft. The drill bit has a cutting/mixing blade, which can vary in diameter from 4 to 12 feet, and is capable of extracting groundwater through the drill bit shaft. Extracted groundwater would be treated through the existing UV/peroxide treatment system. The drill rig can produce up to 350,000 ft lbs of torque, sufficient to provide excellent mixing of subsurface soils as the drill bit descends through the soil column. The drill bit also has multiple injection ports for steam delivery. The multiple ports provide uniform delivery of steam throughout the treatment zone. The caterpillar mounted drill rig is moved from one treatment zone to another sequentially until the entire site is remediated. The treatment columns, or drill shafts, are overlapped by 20% to ensure adequate treatment throughout the entire site. 4 to 6 columns can be treated per day, depending on site conditions. For volatile compounds such as those at OU-1, a negative pressure shroud is placed over the entire treatment zone to capture off-gases for delivery to an off-gas treatment system. Mats are placed under and around the rig to ensure that contaminants do not reach the atmosphere by surfacing outside the shroud. The shroud vacuum is connected to an off-gas treatment system. Systems such as carbon adsorption, catalytic oxidation, and ultraviolet photolysis are all viable for off-gas treatment, but catalytic oxidation is generally the most efficient and economical. An evaluation of off-gas treatment technologies for specific OU-1 contaminants and conditions will be performed during detailed analysis of alternatives.

Removal of groundwater by pumping will be accomplished either by the mobile treatment system or by extraction wells placed near the treatment zone to depress the water table and recover contaminated groundwater. This ensures the recovery of aqueous inorganics present in the groundwater and inorganics dissolved by condensing steam injected by the treatment system. Thus the alternative will address inorganic as well as organic contaminants. The recovered groundwater and condensed steam will be pumped to the existing IM/IRA treatment system at OU-1, which is designed to treat all contaminants found in OU-1 groundwater.

Since this alternative involves removal of the source of contamination, long-term monitoring of groundwater would not be required once the remedial action is complete. Existing groundwater monitoring efforts would, however, be continued for a short period to determine treatment effectiveness.

Effectiveness Evaluation - The in-situ steam extraction with mechanical mixing treatment system is mobile, with a very high treatment capacity relative to other in-situ methods. The system can treat 30 to 80 cubic yards of soil per shaft, depending on site specific conditions and the size of mixing blade used. Each column treatment cycle lasts 2 to 4 hours, taking longer for less volatile contaminants or clayey or silty soils. Thus the system could treat the entire volume targeted for remediation in 47 to 250 days, or 2 to 9 months. Production rates of VOC laden vapors could be as high as 100 cubic yards per hour, so proper sizing of an off-gas collection and treatment system is critical.

Potential impacts of the treatment to human health or the environment during treatment include release of airborne VOCs and hazards from drilling activities. Care would be taken to ensure proper operation of the shroud to eliminate the possibility of airborne release of VOCs. Standard procedures for drilling activities would be followed to minimize risks associated with this part of the treatment activities.

The system has been proven effective in removing halogenated volatile organics from subsurface soils. Soils with a high sand content such as those at OU-1 are particularly amenable to this treatment. Such soils present no difficulties for operation of the mixing blade. Average removal efficiencies of VOCs from previous subsurface soil remediations was 85%, very high for an in-situ treatment. The extent of fracturing in the underlying bedrock is undetermined, but the treatment will have limited effectiveness in treating bedrock contamination due to limitations of the mixing blade in penetrating hard rock formations. The steam extraction process has no effect on non-volatile inorganics, but groundwater removal by pumping will effectively remove those contaminants. Subsurface obstacles, such as buried drums or large rocks, also present a potential difficulty for the treatment. Obstacles larger than 12 inches in diameter must be removed to avoid damage to the equipment. Overall, however, the process is well suited to OU-1 and should be effective in treating contaminants.

Implementability Evaluation - This alternative is readily implementable both technically and administratively. The treatment system is mobile, requiring no construction activities. The primary technical limitation of implementation is the potential of the drill rig to tip on steep surfaces. This could be minimized by grading of steep slopes within the IHSS. Administratively, installation of groundwater extraction wells would require well installation permits, but such permits are readily obtainable. Off-gas treatment would require an air treatment permit, but there is no foreseeable difficulty in obtaining such a permit.

Cost Evaluation - This alternative involves moderate capital costs relative to other processes being considered. The process equipment is available from at least two technology vendors, with slight differences between the two systems. The system is mobile, meaning lease rather than purchase of the equipment is possible. O&M costs are also moderate relative to other alternatives. The dominant O&M cost is energy for steam production, so optimization of steam injection rates would minimize energy costs.

3.3.8 Alternative 5b: In Situ Treatment by Steam Injection with Mechanical Mixing (OU-1)

This alternative is identical with Alternative 5a with the exception that the entire operable unit would be treated as opposed to solely IHSS 119.1. Alternative 5b would utilize the same mobile unit as proposed under Alternative 5a, however the unit would be moved across the site to ensure coverage of all of OU-1. Details concerning operation of this system are presented under the description for Alternative 5a.

Effectiveness Evaluation - The effectiveness of this alternative is limited by the ability to determine exact source locations at areas outside of IHSS 119.1. This alternative would be at least as effective as Alternative 5a since it is treating IHSS 119.1 as in that alternative. However, outside of this area, source locations are much more dispersed and difficult to pinpoint. Effective application of this alternative would require treating most all of the area contained within OU-1 to treat very low initial concentrations of contaminants. In layman terms the technology would have to be applied as "overkill" to ensure that all areas containing residual contaminants were treated.

Implementability Evaluation - For the reasons stated above this alternative would be difficult to implement at OU-1. The drilling method employed treats a soil "column" down to bedrock. To cover the entire site, most all of the soils would be subjected to what amounts to a tilling action which loosens consolidated soil matrices. This action would render the entire hillside unstable and could result in severe slumping and washout. In addition, the treatment unit itself would be subject to an unstable foundation and could result in an unacceptable safety risk to nearby workers.

Cost Evaluation - Capital costs associated with this alternative would not be much greater than those associated with Alternative 5a. A single unit could be implemented to treat the entire operable unit and no additional treatment capacity would be required (i.e., for off-gas or extracted groundwater). The greatest impact to costs associated with this alternative involve O&M costs incurred through a longer period of operation of the french drain treatment system, and through an extended lease of support equipment for the drilling unit.

3.3.9 Alternative 6: Groundwater Removal by Soil Excavation and Sump Pumps (IHSS 119.1 only)

This alternative is intended to reduce or eliminate the risk to a residential receptor at IHSS 119.1 through source removal of contaminated groundwater beneath a discreet portion of the IHSS. This alternative differs from the in situ groundwater treatment alternative in that a portion of unsaturated soils at the IHSS would be excavated down to the water table to allow for the removal of localized groundwater contamination. This is a worst-case scenario which would enable contaminated water to be located and subsequently removed. Such efforts may be required based on the current understanding of the hydrogeologic conditions at OU-1, which suggest complex geology in the area. Site characterization data collected to date have not provided a complete description of the aquifer beneath IHSS 119.1, which may explain the limited effectiveness of the existing groundwater recovery well.

The volume of groundwater requiring treatment and the amount of soil which would have to be excavated for this alternative were calculated based on the results of the Phase III RFI/RI. This alternative would require excavation of approximately 20,000 cubic yards of unsaturated and potentially saturated soils in the southwest corner of IHSS 119.1 (see Figure 3-3). The amount of groundwater collected during the excavation would be approximately 60,000 gallons depending on the seasonal level of the water table. This is a rough estimate of the amount of groundwater present under saturated conditions using the measured porosity of the soils.

Excavation would be terminated slightly below the underlying bedrock to ensure that all contaminated groundwater pools are reached. The groundwater would then be collected using

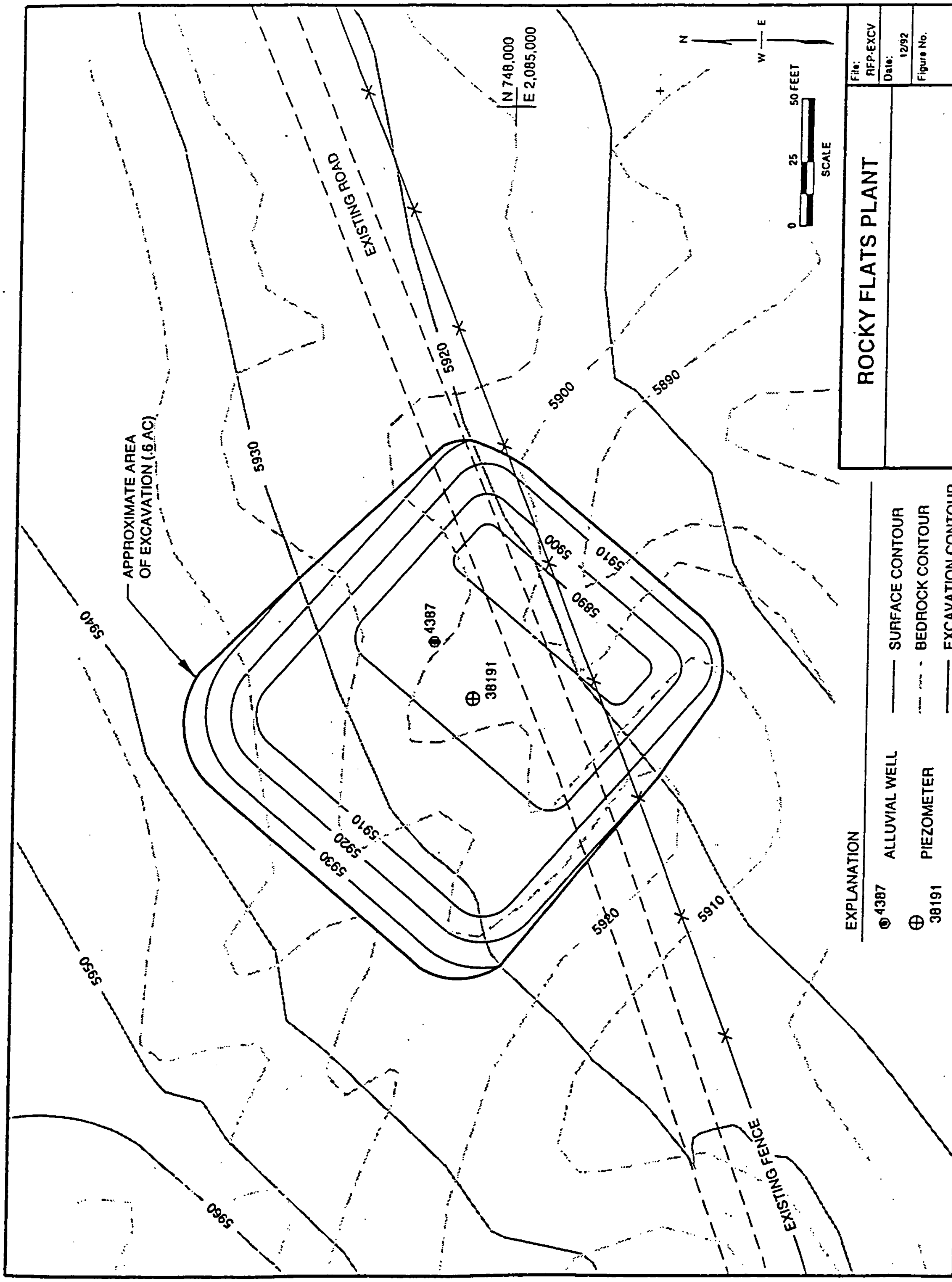


Figure 3-3. Plan View of Excavation Required at IHHS 119.1

sumps installed within the excavation. Standard submersible pumps would be used to direct collected groundwater to the existing IM/IRA treatment system at OU-1 for final treatment and discharge. A piping system from the excavation to the OU-1 treatment facility would be required. This would likely be constructed of PVC and buried to a sufficient depth to prevent freezing. A control system would also be needed to operate pumps as demand required, and to minimize the need for manual oversight and operation.

The actual excavation would be accomplished using conventional construction equipment although breathing apparatus may be included as part of the machinery or may be handled separately on an individual basis. An artificial enclosure could also be installed over the excavation site with a vapor treatment unit attached to collect and treat any volatilized contaminants which escape during excavation.

An important consideration for this alternative would include analyzing and segregating excavated soils to evaluate whether the materials would be considered hazardous waste. Hazardous waste material would require proper treatment and disposal at a licensed treatment, storage, and disposal facility (TSDF), however this may be complicated by the potential presence of plutonium in the soils. Plutonium-contaminated soils would not likely be taken off-site for treatment although they may be sent directly to a low-level waste facility if they do not show hazardous waste characteristics. Excavated soils which do not exhibit above-background levels of contamination would be used as backfill for the excavation following termination of the treatment activities. These soils would need to be stockpiled temporarily until remediation is complete.

Since this alternative involves a removal of the source of contamination, long-term monitoring of groundwater would not be required once the remedial action is complete. Existing groundwater monitoring programs would be continued, however, to evaluate the impact that he removal action had on the system. Short-term monitoring of vapor concentrations in air would be required during the excavation and prior to its closure.

Effectiveness Evaluation - Because of the complicated hydrogeology present at OU-

1, this type of alternative would allow for a greater overall effectiveness in removal of contaminated groundwater by providing direct access to IHSS 119.1 groundwater. The existing IM/IRA treatment system is already in place at OU-1 to effectively treat the contaminated water removed from IHSS 119.1.

Removal of the contaminated materials (followed by treatment) from the vicinity of IHSS 119.1 will allow for complete removal of residual contamination from the saturated zone, thus satisfying the statutory preference for reduction of toxicity, mobility, or volume through treatment. Sump pumps would effectively collect any dissolved phase contaminants for treatment by the IM/IRA system. This alternative would involve complete removal of source contamination, leaving no potential for future release from residual contamination, and satisfying requirements both short- and long-term protection of human health and the environment.

Implementability Evaluation - This alternative would be readily implementable if it was selected as the preferred remedial action alternative. The equipment required for the alternative is commonly available and does not require any specialized construction and/or operation personnel. Extraction wells (sumps) are widely used and equipment could be obtained from a number of suppliers. Vapor treatment systems are also commonly constructed for use with commercially available materials.

The existing IM/IRA treatment system has already been constructed and is available for use at OU-1. During operation, none of these systems would exceed government regulations (by design) for emissions of either vapor-phase or aqueous-phase contaminants. Spent ion-exchange resins would be sent to an approved disposal or recycling facility and would not cause administrative difficulties.

The only significant problem identified at this time is the potential for large quantities of contaminated soils to be generated requiring disposal at a commercial TSDF. The disposal of these soils may cause potential difficulties if they are found to be both radioactive and RCRA hazardous.

Cost Evaluation - The capital cost requirements for this alternative are relatively low as a fairly small number of sump pumps wells would be required and the existing IM/IRA treatment system has already been constructed. O&M costs would be moderate for this alternative compared to other alternatives considered due to the extensive manpower required for soils excavation and groundwater treatment. The costs for disposal of the excavated soils could range from relatively low (if most soil could be reused for backfill) to very high if all soils required treatment and/or disposal at a commercial TSDF.

3.3.10 Alternative 7: Containment by Capping w/Institutional Controls (IHSS 119.1 only)

This alternative would provide for the capping of the vicinity of IHSS 119.1 in order to prevent infiltration of rainwater, surface water, and snow melt from reaching and mobilizing wastes in the IHSS, to prevent escape of vapors from the IHSS to the atmosphere, and to contain surface soil hotspots (areas of high radiological contamination). Capping is the systematic covering of an area with layers of soil, clay, or synthetic material to impart certain physical or chemical characteristics such as slope, impermeability, or chemical resistance to the surface. Typical applications of capping are municipal landfills where leachate is formed via infiltrating surface water. Mine wastes have also been capped to eliminate not only the migration of metals into groundwater through seepage, but also contamination of surface water, soils, or air through erosion of the waste surface. In this case, the overall objective of this alternative would be to provide drainage and minimize escape of organic vapors to the atmosphere. Meeting this objective would minimize potential exposure pathways through inhalation of vapors in the basements of existing and future structures. Design of a cap for IHSS 119.1 must take into account the topography of the surface of the IHSS and the stability of the 881 Hillside. Climate and hydrology of RFP must be considered for the design to prevent flood hazards and to address the needs of cap vegetative material or gravel cover. Any cap proposed for OU-1 would require enough fill material to provide a level foundation of the capping material.

To prevent atmospheric release of vapors, a simple low permeability cover is sufficient. In this case, a low permeability clay cap with an overlying vegetative or gravel layer would be used. If necessary, a RCRA multilayer-type cap could be used. In a multiple layer cap, a vegetative or gravel cover provides the surface with protection from erosion by wind and water; a geotextile layer provides strength; a granular layer facilitates drainage of infiltrated water; a compacted natural clay or geosynthetic layer (i.e., Bentomat) provides a water impermeable barrier; and an intermediate soil cover provides a smooth surface for the clay layer and proper slope for drainage. An optional flexible membrane liner (FML) may be added to prevent gas or liquid migration up through the cap. The multiple layer cap is based on standard RCRA closure requirements and may be required as mentioned above. The simpler, single layer cap should suffice, however, to prevent atmospheric releases.

Effectiveness Evaluation - Surface capping of landfills has been used successfully for CERCLA and RCRA sites in the past, including municipal landfills and hazardous waste disposal facilities. Typically, hazardous waste disposal facilities will also include a liner system beneath the waste to prevent groundwater contact and to collect leachate, while municipal facilities may only have a surface cap if liner technology was not in use when the landfill was initiated. A cap at OU-1 would reduce airborne release of contaminants by isolating therm from the atmosphere, as well as contain the surface soil radiological hotspots. The alternative, however, would provide no additional protectiveness of human health beyond institutional controls. Institutional controls must be maintained with a cap to ensure that no wells or structures breech the impermeable clay layer, or that deterioration of the liner does not occur. Without a venting and off-gas treatment system, vapors would build up within the cap until concentration gradients caused vapor diffusion beyond the boundaries of the cap. Thus the cap would not permanently contain the vapors and might even increase contaminant migration by eliminating atmospheric release and allowing vapors to migrate laterally. Any cracking of the clay layer or punctures in an FML would serve as a release point for contaminants with potentially very high concentrations.

Implementability Evaluation - Capping is a readily implementable technology. Construction materials are generally available for capping activities. Standard construction procedures for roadway and building construction may be used in the construction of covers. Excavation, material preparation, soil placement, soil compaction, geomembrane installation, placement of drainage structures, and cap sloping are commonly performed activities. Capping can be easily implemented using readily available roadway construction equipment.

Routine maintenance of a cap may require irrigation and mowing of vegetation at the surface. Replacement of components of the cap should not be necessary. Cap monitoring for vapor leakage would be extremely difficult due to the difficulty in sampling over the entire cap area. Additional construction concerns such as erosion of the exterior cap and failure of membranes due to subsidence and slumping within the IHSS are difficult to correct, but may be avoided by careful selection of materials, proper compaction, and adequate grading and sloping. No permits would be required for capping as it would be conducted on site.

Cost Evaluation - The cost of capping is dependent upon the materials used for construction. If local materials are readily available and a cap does not require synthetic membrane liners, cost for capping is limited by quantities of local materials needed.

The capital cost of capping IHSS 119.1 would be moderate relative to other remedial action alternatives providing similar levels of protectiveness. O&M costs would be moderate to low.

3.4 Summary of Alternative Screening

The primary purpose of the screening of remedial action alternatives is to reduce the number of alternatives that undergo detailed analysis to a more manageable number of options that still represent conceptually different approaches towards site remediation. The criteria of effectiveness, implementability, and cost were each carefully examined with respect to the alternatives presented in this section. The results of the screening indicate that the following alternatives will be eliminated from further consideration:

- Alternative 2: Limited Action
- Alternative 3: Groundwater Removal by Pumping (OU-1)
- Alternative 5b: In Situ Treatment by Steam Injection with Mechanical Mixing

(OU-1)

- Alternative 7: Containment by Capping w/Institutional Controls (IHSS 119.1 only)

Alternative 2 was eliminated from further consideration because of its effectiveness relative to Alternative 1. Based on the data presented in the *System Operation and Optimization Test Report* (DOE 1992) for the IM/IRA, the French Drain would not contribute additional protection of human health and the environment beyond that provided by institutional controls alone. In addition, Alternative 2 would result in substantially higher costs due to the O&M costs incurred in operating the IM/IRA treatment system. Because Alternative 2 does not provide greater effectiveness than Alternative 1 and yet results in much higher costs, it is not considered for further analysis.

Alternative 3 was eliminated from further consideration due to its limited effectiveness and implementability. Both of these criteria are severely limited by the hydrology at OU-1. The existing recovery well has historically provided sporadic groundwater recovery due to variable water levels and low saturated thicknesses in the area. The radius of influence of any additional wells would likewise be limited and would be negatively impacted by the bedrock geology which tends to form slumps and paleochannels which channel and sometimes confine groundwater "pools". For these reasons this alternative will not be considered further.

Alternative 5b involves the application of a mechanical mixing device to the site as a whole. Because the nature of contamination beneath OU-1 is such that very low concentrations of contaminants occur sporadically across the site, it is unlikely that the drilling device could be accurately situated over source locations. On an OU-1 sitewide basis the drilling system under consideration would require impacting all of the soils at the hillside. This could affect a potentially dangerous situation by loosening the soils to the point of release. Slumping was a problem discovered during installation of the French Drain which would be magnified by attempting to steam and auger treat the entire operable unit. This alternative was therefore eliminated from further consideration.

Lastly, Alternative 7 was eliminated from further consideration on the basis of effectiveness. Capping IHSS 119.1 would not provide additional protection beyond simple institutional controls and would cost more to implement. Capping would require controls to avoid penetration of the cap by drilling activities or construction, both of which would be controlled by the institutional controls proposed under Alternative 1.

Therefore, the alternatives which survived the alternative screening process, and are being retained for evaluation for action-specific ARARs, and subsequently detailed analysis are:

- Alternative 0: No Action
- Alternative 1: Institutional Controls
- Alternative 4a: In Situ Treatment by RF/Ohmic Heating with SVE (IHSS 119.1 only)
- Alternative 4b: In Situ Treatment by RF/Ohmic Heating with SVE (OU-1)
- Alternative 5a: In Situ Treatment by Steam Injection with Mechanical Mixing (IHSS 119.1 only)
- Alternative 6: Groundwater Removal by Soil Excavation and Sump Pumps (IHSS 119.1 only)

4.0 POTENTIAL ACTION-SPECIFIC ARARs AND TBCs

The NCP [40 CFR 300.400(g)] requires identification of potential ARARs for remedial action alternatives proposed at CERCLA sites. Identification of potential ARARs is required by Section 121 (d)(2) of CERCLA, as amended, and as described in the IAG.

The focus of this section is in on identification of potential action-specific ARARs according to the criteria listed in the NCP regulations under 40 CFR 300.400(g)(1) and (2). Proposed remedial action alternatives for the OU-1 site have been analyzed to identify potential requirements that might be applicable or relevant and appropriate to the action. In addition, EPA's guidance in identifying action-specific ARARs was reviewed during the analysis to verify that the methodology used in identifying ARARs for OU-1 was consistent with that used at other sites.

Action-specific ARARs address an activity, condition, or technology involving limitations of specific substances or materials. Additional information on action-specific ARARs is published in the NCP regulations and in EPA's *CERCLA Compliance with Other Laws Manual, Interim Final* (EPA 1988b).

Tables 4-1 and 4-2 identify potential Federal and State action-specific ARARs and To-Be-Considered (TBC) criteria. Tables 4-3 and 4-4 identify the potential action-specific ARARs and TBCs which will be evaluated for each proposed alternative during the detailed analysis of alternatives. As alternatives are further refined during the detailed analysis, additional action-specific requirements may also be identified or existing requirements modified, based on the initial list.

Table 4-1.
Potential Federal
Action-Specific ARARs and TBCs

Standard, Requirement Criteria, or Limitation	Citation	Description	Potential ARARs or To Be Considered Criteria
Resource Conservation and Recovery Act (RCRA)	42 USC Secs. 6901-6987	See below.	
A. Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	Establishes criteria for solid waste disposal facilities which pose a threat to human health or the environment.	ARAR
B. Hazardous Waste Management Systems: General	40 CFR Part 260	Establishes definitions as well as procedures and criteria for application, modification, or revocation of any provision in 40 CFR Parts 260-265.	ARAR
C. Identification and Listing of Hazardous Wastes	40 CFR Part 261	Defines those solid wastes which are subject to regulation as hazardous wastes under RCRA Subtitle C.	ARAR
D. Proposed Definition of Hazardous Waste to Exclude Environmental Media[1]	40 CFR Part 260, 261, and 268	Establishes alternative standards for soil contamination with prohibited hazardous wastes.	TBC
E. Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	Establishes standards for generators of hazardous waste.	ARAR
F. Releases from Solid Waste Management Units	40 CFR Part 264, Subpart F	Establishes corrective action requirements.	ARAR
G. Closure and Post-Closure	40 CFR Part 264, Subpart G	Establishes closure requirements.	ARAR
H. Use and Management of Containers	40 CFR Part 264, Subpart I	Establishes storage requirements.	ARAR
I. Landfills	40 CFR Part 264, Subpart N	Establishes disposal requirements.	ARAR
J. Miscellaneous Units	40 CFR Part 264, Subpart X	Establishes performance standards.	ARAR
K. Air Emission Standards for Process Vents	40 CFR Part 264, Subpart AA	Establishes air emissions standards for hazardous wastes ≥ 10 ppmw TOCs.	ARAR
L. Air Emission Standards for Equipment Leaks	40 CFR Part 264, Subpart BB	Establishes air emission standards for equipment where wastes $\geq$ 10% TOCs.	ARAR
M. Proposed Air Emission Standards for Storage Units	40 CFR Part 264, Subpart CC	Establishes air emission standards for tanks, impoundments, and containers of waste $\geq$ 500 ppmw VOCs.	TBC
N. Design Standards for Containment Buildings	40 CFR Part 264, Subpart DD	Establishes fugitive dust standards for stored wastes.	ARAR

Table 4-1.
Potential Federal
Action-Specific ARARs and TBCs

Standard, Requirement Criteria, or Limitation	Citation	Description	Potential ARARs or To Be Considered Criteria
O. Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 265	Establishes minimum national standards that define the acceptable management of hazardous waste during the period of interim status and until certification of final closure, or if the facility is subject to post-closure until responsibilities are fulfilled.	ARAR
P. Interim Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities	40 CFR Part 267	Establishes minimum national standards that define acceptable management of hazardous waste for new land disposal facilities.	ARAR
Q. Land Disposal Restrictions	40 CFR Part 268	Establishes restrictions for the land disposal of hazardous wastes.	ARAR
R. Underground Storage Tanks	40 CFR Part 280	Establishes technical standards and corrective action requirements for owners/operators of underground storage tanks (USTs).	ARAR
Toxic Substances Control Act	15 USC Secs. 2601-2629	See below.	
A. PCB Requirements	40 CFR Part 761	Establishes storage and disposal requirements for PCBs exceeding 50 ppm.	ARAR
Clean Water Act	33 USC Secs. 1251-1376	See below.	
A. Discharge of Effluent FF. CA - CWA-90-1 NPDES Federal Facility Compliance Agreement	40 CFR Sec. 125.100 40 CFR Sec. 122.41	Requires that best management practices be maintained by the operator of a system which discharges pollutants directly into the environment and requires that point source discharges be monitored to assure compliance with effluent discharge limits.	ARAR
B. Toxic Pollutant Effluent Standards	40 CFR 129	Establishes numeric standards and limitations from specific sources for Aldrin/dieldrin; DDT; Endrin; Toxaphene; Benzidine; and PCBs.	ARAR
C. Discharge of Stormwater	40 CFR Sec.122.21 40 CFR Sec. 122.26	Controls point source discharges of stormwater associated with industrial activity; including requirements for pollution prevention plan. Industrial activity includes landfills, land application sites, and construction activities.	ARAR
Atomic Energy Act	42 USC Secs. 2011 et seq.		
A. Radiation Protection and Radioactive Waste Management	10 CFR Part 20 Subparts C and K	Establishes minimum standards for radiation protection and waste management.	ARAR
B. Performance Objective in Licensing for Land Disposal of Radioactive Waste	10 CFR Part 61	Establishes procedures, criteria, and conditions for land disposal of radioactive waste.	ARAR

Table 4-1.
Potential Federal
Action-Specific ARARs and TBCs

Standard, Requirement Criteria, or Limitation	Citation	Description	Potential ARARs or To Be Considered Criteria
Clean Air Act	42 USC Secs. 7401-7642		
A. Prevention of Significant Deterioration Requirements	40 CFR 52	Establishes new source review policy for "major" sources to prevent degradation of air quality.	ARAR
B. National Emission Standards for Hazardous Air Pollutants	40 CFR 61	Regulates emissions of hazardous air pollutants from specific source categories, including site remediation.	ARAR
DOE Orders[1]			
General Environmental Protection Program	5400.1	Specifies environmental protection standards applicable to DOE operations.	TBC
Environmental Compliance Issue Coordination	5400.2A	Specifies establishment of environmental protection program to comply with environmental laws.	TBC
Radiation Protection of the Public and Environment	5400.5	Specifies compliance of DOE and its contractors under AEA, radiation protection requirements.	TBC
Environment Safety and Health Programs for DOE Operations	5480.1B	Specifies responsibility of DOE and conditions under which operations are to be curtailed due to risks.	TBC
Radioactive Waste Management	5480.2A	Specifies environmental protection requirements and compliance with requirements.	TBC
Hazardous and Radioactive Mixed Hazardous Waste Management	5480.3	Specifies the transportation and packaging requirements for hazardous materials applicable to DOE and its contractors.	TBC
Environmental Protection, Safety, and Health Protection Standards	5480.4	Specifies environmental, health, and safety requirements for facility construction, operation, and decommissioning; including the environmental statutory requirements applicable to DOE and contractors.	TBC

[1]To be considered.

Table 4-2.
Potential State
Action-Specific ARARs and TBCs

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARARs or To Be Considered Criteria
Colorado Hazardous Waste Act and State Hazardous Waste Siting Act	CRS § 25-15-101 et seq., 25-15-200-et seq., 25-15-301 et seq.	See below.	
Hazardous Waste Management Regulations Identification and Listing of Hazardous Waste	6 CCR 1007-3 Part 261	Defines those solid wastes which are subject to regulation as hazardous wastes.	ARAR
Standards Applicable to Generators of Hazardous Waste	6 CCR 1007-3 Part 262,	Establishes the criteria for generators managing hazardous waste.	ARAR
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	6 CCR 1007-3 Part 264	Establishes standards that define acceptable management of hazardous waste for owners and operators of facilities which treat, store, or dispose of hazardous waste.	ARAR
Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	6 CCR 107-3 Part 265	Establishes standards that define acceptable management of hazardous waste for owners and operators of facilities which treat, store, or dispose of hazardous waste before final Part B permit approval.	ARAR
Land Disposal Restrictions	6 CCR 1007-3 Part 268	Establishes restrictions on the land disposal of hazardous waste	ARAR
Colorado Solid Waste Disposal Sites and Facilities Act	CRS § 30-20-100.5 et seq.	See below.	
Colorado Solid Waste Disposal Sites and Facilities Regulations	6 CCR 1007-2	Establishes solid waste disposal criteria including the collection, storage, treatment, utilization, processing, and final disposition of solid wastes.	ARAR
Colorado Water Quality Control Act	CRS 24-4-103(3), and (8)		
A. Effluent Limitations	5 CCR 1002 10.1.4	Establishes standards for all wastewaters, except storm and agricultural runoff, discharged to State waters.	ARAR
B. Basic Standards and Methodologies for Surface Water Quality	5 CCR 1002.8 3.1.0 et seq.	Establishes standards and classifications for surface waters of State.	ARAR
C. Classifications and Water Quality Standards for Groundwater	6 CCR 1007.3, 5 CCR 1002-8, 3.11.5-3.11.8	Establishes standards/criteria and classifications for groundwater.	TBC
Colorado Air Pollution Prevention Control Act, as amended	CRS 25-7-112	See below.	

Table 4-2.
Potential State
Action-Specific ARARs and TBCs

Standard, Requirement, Criteria, or Limitation	Citation	Description	Potential ARARs or To Be Considered Criteria
Colorado Air Pollution Control Regulations, Air Pollutant Emission Notice Requirements	5 CCR 1001-5 Regulation 3, Subpart A	Defines sources subject to Air Pollution Emission Notice Regulations	ARAR
State Construcion Permits	5 CCR 1001-5 Regulation 3, Subpart B	Defines permitting thresholds for sources in attainment and non-attainment areas. Requires constuction permits for major sources.	ARAR
Operating Permit Program	5 CCR 1001-5 Regulation 3, Subpart C	Implements the Federal operating program for "major" sources of air pollutants.	ARAR
Soil Erosion Dust Blowing Act	CRS 35-72-101 et seq.	Applicable to all land disturbing activities. Provides for the conservation of surficial soils.	ARAR
Act to Establish Power and Duties of Board of Health; Department of Health	CRS § 25-1-107, 25-1-108, and 25-11-104		
Colorado Rules and Regulations Pertaining to Radiation Control	See below.	See below.	
A. Radioactive Material Other than Source Material	6 CCR 1007-1.1 Part III RH 3.3.1 - Schedule A	Determines concentration limits for radioactive materials that exceed background concentrations.	ARAR
B. Standards for Protection Against Radiation	6 CCR 1007-1 Part IV RH 4.2.1-4.2.2.3	Establishes radiation dose limits to individuals in controlled areas.	ARAR
Colorado Noise Abatement Statute	CRS 25-12-101, et seq.	Establishes standards for controlling noise.	ARAR
Storage Tank Facility Owner/Operator Guidance Documents	Colorado Department of Health, December 1992	State cleanup guidelines for contaminated materials.	TBC

Table 4-3.
Potential Federal
Action-Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls	4a and 4b In Situ Treatment by RF/Ohmic Heating with SVE	5a In Situ Treatment by Steam Injection with Mechanical Mixing	6 Groundwater Removal by Soil Excavation and Sump Pumps
Resource Conservation and Recovery Act (RCRA)	42 USC Secs. 6901-6987					
A. Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	X	X	X	X	X
B. Hazardous Waste Management Systems: General	40 CFR Part 260	X	X	X	X	X
C. Identification and Listing of Hazardous Wastes	40 CFR Part 261	X	X	X	X	X
D. Proposed Definition of Hazardous Waste to Exclude Environmental Media[1]	40 CFR Part 260, 261, and 268	X	X	X	X	X
E. Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262			X	X	X
F. Releases from Solid Waste Management Units	40 CFR Part 264, Subpart F	X	X	X	X	X
G. Closure and Post-Closure	40 CFR Part 264, Subpart G	X	X	X	X	X
H. Use and Management of Containers	40 CFR Part 264, Subpart I			X	X	X
I. Landfills	40 CFR Part 264, Subpart N			X	X	X
J. Miscellaneous Units	40 CFR Part 264, Subpart X			X	X	X
K. Air Emission Standards for Process Vents	40 CFR Part 264, Subpart AA			X	X	X
L. Air Emission Standards for Equipment Leaks	40 CFR Part 264, Subpart BB			X	X	X
M. Proposed Air Emission Standards for Storage Units	40 CFR Part 264, Subpart CC			X	X	X
N. Design Standards for Containment Buildings	40 CFR Part 264, Subpart DD			X	X	X
O. Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 265	X	X	X	X	X

Table 4-3.
Potential Federal
Action-Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0	1	4a and 4b	5a	6
		No Action	Institutional Controls	In Situ Treatment by RF/Ohmic Heating with SVE	In Situ Treatment by Steam Injection with Mechanical Mixing	Groundwater Removal by Soil Excavation and Sump Pumps
P. Interim Status Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities	40 CFR Part 267	X	X	X	X	X
Q. Land Disposal Restrictions	40 CFR Part 268			X[2]	X[2]	X
Toxic Substances Control Act	15 USC Secs. 2601-2629					
A. PCB Requirements	40 CFR Part 761	X		X	X	X
Clean Water Act	33 USC Secs. 1251-1376					
A. Discharge of Effluent FF. CA - CWA-90-1 NPDES Federal Facility Compliance Agreement	40 CFR Sec. 125.100 40 CFR Sec. 122.41	X	X	X	X	X
B. Toxic Pollutant Effluent Standards	40 CFR 129	X	X	X	X	X
C. Discharge of Stormwater	40 CFR Sec.122.21 40 CFR Sec. 122.26	X	X	X	X	X
Atomic Energy Act	42 USC Secs. 2011 et seq.					
A. Radiation Protection and Radioactive Waste Management	10 CFR Part 20 Subpart C and K	X	X	X	X	X
B. Performance Objectives in Licensing for Land Disposal of Radioactive Waste	10 CFR Part 61	X	X	X	X	X
Clean Air Act	42 USC Secs. 7401-7642					
A. Prevention of Significant Deterioration Requirements	40 CFR 52			X	X	
B. National Emission Standards for Hazardous Air Pollutants	40 CFR 61			X	X	

Table 4-3.
Potential Federal
Action-Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls	4a and 4b In Situ Treatment by RF/Ohmic Heating with SVE	5a In Situ Treatment by Steam Injection with Mechanical Mixing	6 Groundwater Removal by Soil Excavation and Sump Pumps
DOE Orders[1]						
General Environmental Protection Program	5400.1	X	X	X	X	X
Environmental Compliance Issue Coordination	5400.2A	X	X	X	X	X
Radiation Protection of the Public and Environment	5400.5	X	X	X	X	X
Environment Safety and Health Programs for DOE Operations	5480.1B	X	X	X	X	X
Radioactive Waste Management	5480.2A	X	X	X	X	X
Hazardous and Radioactive Mixed Hazardous Waste Management	5480.3	X	X	X	X	X
Environmental Protection, Safety, and Health Protection Standards	5480.4	X	X	X	X	X

[1]To be considered.
[2]Applies to treatment residuals only.

Table 4-4.
Potential State
Action-Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls	4a and 4b In Situ Treatment by RF/Ohmic Heating with SVE	5a In Situ Treatment by Steam Injection with Mechanical Mixing	6 Groundwater Removal by Soil Excavation and Sump Pumps
Colorado Hazardous Waste Act and State Hazardous Waste Siting Act	CRS § 25-15-101 et seq., 25-15-200-et seq., 25-15-301 et seq.					
Hazardous Waste Management Regulations Identification and Listing of Hazardous Waste	6 CCR 1007-3 Part 261	X	X	X	X	X
Standards Applicable to Generators of Hazardous Waste	6 CCR 1007-3 Part 262,			X	X	X
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	6 CCR 1007-3 Part 264	X	X	X	X	X
Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	6 CCR 1007-3 Part 265	X	X	X	X	X
Land Disposal Restrictions	6 CCR 1007-3 Part 268			X[1]	X[1]	X
Colorado Solid Waste Disposal Sites and Facilities Act	CRS § 30-20-100.5 et seq.					
Colorado Solid Waste Disposal Sites and Facilities Regulations	6 CCR 1007-2	X	X	X	X	X
Colorado Water Quality Control Act	CRS 24-4-103(3), and (8)					
A. Effluent Limitations	5 CCR 1002, 10.1.4	X	X	X	X	X
B. Basic Standards and Methodologies for Surface Water Quality	5 CCR 1002-8 3.1.0 et seq.	X	X	X	X	X
C. Classifications and Water Quality Standards for Groundwater	6 CCR 1007.3, 5 CCR[1] 1002-8, 3.11.5-3.11.8	X	X	X	X	X

Table 4-4.
Potential State
Action-Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls	4a and 4b In Situ Treatment by RF/Ohmic Heating with SVE	5a In Situ Treatment by Steam Injection with Mechanical Mixing	6 Groundwater Removal by Soil Excavation and Sump Pumps
Colorado Hazardous Waste Act and State Hazardous Waste Siting Act	CRS § 25-15-101 et seq., 25-15-200-et seq., 25-15-301 et seq.					
Colorado Air Pollution Prevention Control Act, as amended	CRS 25-7-112					
Colorado Air Pollution Control Regulations, Air Pollutant Emission Notice Requirements	5 CCR 1001-5 Regulation 3, Subpart A			X	X	
State Construction Permits	5 CCR 1001-5 Regulation 3, Subpart B			X	X	
Operating Permit Program	5 CCR 1001-5 Regulation 3, Subpart C			X	X	
Soil Erosion Dust Blowing Act	CRS 35-72-101 et seq.	X	X	X	X	X
Act to Establish Power and Duties of Board of Health; Department of Health	CRS § 25-1-107, 25-1-108, and 25-11-104					
Colorado Rules and Regulations Pertaining to Radiation Control	See below.	X	X	X	X	X
A. Radioactive Material Other than Source Material	6 CCR 1007-1.1 Part III RH 3.3.1 - Schedule A	X	X	X	X	X
B. Standards for Protection Against Radiation	6 CCR 1007-1 Part IV RH 4.2.1-4.2.2.3	X	X	X	X	X

Table 4-4.
Potential State
Action-Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0	1	4a and 4b	5a	6
		No Action	Institutional Controls	In Situ Treatment by RF/Ohmic Heating with SVE	In Situ Treatment by Steam Injection with Mechanical Mixing	Groundwater Removal by Soil Excavation and Sump Pumps
Colorado Hazardous Waste Act and State Hazardous Waste Siting Act	CRS § 25-15-101 et seq., 25-15-200-et seq., 25-15-301 et seq.					
Colorado Noise Abatement Statute	CRS 25-12-101, et seq.			X	X	X
Storage Tank Facility Owner/Operator Guidance Documents	Colorado Department of Health, December 1992[1]	X	X	X	X	X

[1]Applies to treatment residuals only.

5.0 REFERENCES

Aines, R., Udell, K., *Dynamic Underground Stripping Project*, Lawrence Livermore National Laboratory, Livermore, California.

Buettner, H. M. Daily, W. D., *Enhancing Vacuum Extraction of Volatile Organics Using Electrical Heating*, Health Sciences Department, Lawrence Livermore National Laboratory, Livermore, California.

Corbitt, R. A., 1990, *Standard Handbook of Environmental Engineering*, McGraw-Hill Publishing Company, New York, New York.

Danko, J., 1989, *Applicability and Limits of Soil Vapor Extraction For Sites Contaminated with Volatile Organic Compounds*, CH_2M Hill, Corvalis, Oregon.

DOE 1992, *Systems Operation and Optimization Test Report, Interim Measure/Interim Remedial Action for the 881 Hillside Operable Unit 1*, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, November 1992.

DOE 1993, *Final Phase III RFI/RI, Rocky Flats Plant, 881 Hillside Area (Operable Unit 1)*, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, November 1993.

DOE 1994, *Development of Remedial Action Objectives, 881 Hillside Area (OU-1), Technical Memorandum No. 10, Final*, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, January 1994.

Driscoll, F. G., 1986, *Groundwater and Wells, 2nd Ed.*, Johnson Division, St. Paul, Minnesota.

EG&G 1992, *OU-1 Domestic Water Supply Simulations*, EG&G Rocky Flats, Geosciences Division, December 1992.

EPA 1986, *Mobile Treatment Technologies for Superfund Wastes*, EPA/540/2-86/003f, September 1986.

EPA 1988a, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA 1988b, *CERCLA Compliance with Other Laws Manual: Interim Final*, EPA/540/G-89/006, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA 1990, *National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule*, Federal Register Volume 55, Number 46, U.S. Environmental Protection Agency.

EPA 1991, *Soil Vapor Extraction Technology, Reference Handbook*, EPA/540/2-91/003, February 1991.

EPA 1992, *Results of a Pilot Scale Study of Enhanced Biotransformation of Halogenated Alkenes by Methanotrophic Bacteria*, Methodologies for Evaluating In-Situ Bioremediation of Chlorinated Solvents, EPA/600/R-92/042, March 1992.

Freeman, H. M. et al., 1989, *Standard Handbook of Hazardous Waste Treatment and Disposal*, McGraw-Hill Publishing Company, New York, New York.

Green, Don W., ed., *Perry's Chemical Engineers' Handbook, Sixth Edition*, McGraw-Hill Book Company, New York, New York.

Heath, W.O., 1992, *Investigation of Electric Fields for Low-Temperature Treatment of Soils and Liquids*, Pacific Northwest Laboratory, Richland, Washington, February 1992.

IAG 1991, *Rocky Flats Interagency Agreement Between the State of Colorado, the Environmental Protection Agency, and the Department of Energy.*

Johnson, P. C. et al., 1989, *A Practical Approach to the Design, Operation, and Monitoring of In-Situ Soil Venting Systems*, Shell Development/Shell Oil Company, Westhollow Research Center, Houston, Texas.

Kasevich, R. S., 1992, *Application of RF Technology to In-Situ Treatment of Nuclear Wastes and Mixed Wastes Containing Radioactive Isotopes and Organic Chemicals*, KAI Technologies, Inc., Woburn, Massachusetts.

Kemmer, Frank N., ed., 1988, *The NALCO Water Handbook, Second Edition*, McGraw-Hill Book Company, New York, New York.

McCarty, P. L. et al., 1991, *In-Situ Bioremediation for Groundwater at St. Joseph, Michigan*, On Site Bioreclamation: Processes for Xenobiotic and Hydrocarbon Treatment, Robert E. Hinchee and Robert F. Olfenbuttel eds., Butterworth-Heinemann, Boston, Massachusetts.

McCullough, Matthew L., Morabito, J.R., 1994, *Closure strategies for soil-vapor extraction systems*, Hazmat World, February 1994.

MecTool: Advanced Techniques for In Situ Remediation, Millgard Environmental Corporation, Livonia, Michigan.

Semprini, L. and P. L. McCarty, 1992, *Comparison Between Model Simulations and Field Results for In-Situ Biorestoration of Chlorinated Aliphatics: Part 2. Cometobolic Transformations*, Ground Water, February 1992.

Stinson, M. K., 1989, *EPA SITE Demonstration of the Terra Vac In Situ Vacuum Extraction Process in Groveland, Massachusetts*, Journal of the Air and Waste Management Association, Volume 39, Number 8.

Wagner, K., et al, 1986, *Remedial Action Technology for Waste Disposal Sites, Second Edition*, Noyes Data Corporation, Park Ridge, New Jersey.

ATTACHMENT I

TECHNOLOGIES AND PROCESS OPTIONS FOR PLUTONIUM AND PAHS IN SOILS

The purpose of this attachment is to summarize work completed under the Rocky Flats Plant (RFP) Operable Unit 1 (OU1) Corrective Measures Study/ Feasibility Study (CMS/FS) regarding radionuclide and semi-volatile organic contamination in surface soils. Surface soil radiological contamination has been included within the scope of the Operable Unit 2 (OU-2) CMS/FS, however, technology identification and screening of remedial technologies was performed prior to the determination to include OU-1 surface soils in the larger OU-2 contamination plume. Work completed to date on identification, screening, and evaluation of technologies appropriate for contaminants identified in OU-1 surface soils is presented through the attached tables (see back of text).

Identification of potential remedial technologies for radiologic contamination in surface soils was accomplished through current literature reviews, vendor contacts, and input of Dames & Moore personnel with experience with radiological contamination. This technology identification resulted in the development of an extended list of potential technologies for consideration at OU-1 and the RFP as a whole.

In addition to the screening and evaluation of technologies presented in the attached tables, specific technologies which are considered relatively innovative were examined in detail for their potential applicability to the radionuclide contamination found in OU-1. These technologies, *high gradient magnetic separation, segmented gate system, and TRUclean* are discussed in the following paragraphs.

High Gradient Magnetic Separation

High Gradient Magnetic Separation (HGMS) is an innovative technology being considered for the removal of materials such as plutonium and americium from matrices such as typical soils. It applies a high strength magnetic field to the contaminated matrix, causing separation of constituents based on magnetic susceptibility. Materials can be classified into two general categories: (1) diamagnetic solids that are repelled by a magnetic field, and (2) paramagnetic solids that are attracted by a magnetic field. Paramagnetic solids can then be subcategorized as either strongly paramagnetic (ferromagnetic), weakly paramagnetic, and nonmagnetic.

Plutonium and americium are highly paramagnetic, while organic matter and soil components at RFP are nonmagnetic, which is the basis for the separation.

Magnetic separation applies a powerful magnetic field to the contaminated matrix in order to effect a separation of paramagnetic constituents from nonmagnetic and diamagnetic constituents. The contaminated matrix is fed to the system in either dry or slurried form. The wet basis option is described here as a representative process option. The HGMS system isolates paramagnetic materials by processing a slurried influent stream, with typical solids compositions ranging from 30 to 50% by weight. Slurrying typically enhances the isolation of plutonium by suspending it in the aqueous matrix, yielding process effectiveness in removing particulate plutonium contamination. The critical operating parameters of an HGMS system are the magnetic field strength, the residence time of the slurried material, the slurry composition (solid/liquid ratio), and the type and geometry of the capture matrix. The capture matrix is a material lining the outside of the magnetic field chamber, typically stainless steel wool, which traps the paramagnetic constituents as they are drawn toward the magnetic field. Typically a capture matrix can trap up to 10% of its weight before saturating and requiring removal. Magnetic field strength is a function of power supplied to the HGMS unit, with field strength proportional to the square root of the power applied. Thus doubling the field strength would require increasing power input by 4 times. Increased magnetic field strength increases removal efficiency of paramagnetic materials. The proper field strength must be determined by treatability studies, with the optimal field maximizing removal of target contaminants while minimizing effects on non target constituents. Typical HGMS units can treat between 5 and 60 tons of solid per hour, with field strengths between 10 and 20 kilogauss. Both batch and continuous options are available. Support equipment includes a feed preparation system to slurry and screen the contaminated soil, and water polishing to recover plutonium from wash water used to clean the capture matrix. Figure I-1 depicts the unit operations involved in magnetic separation.

The soil exiting the HGMS should be below the release criteria and suitable for drying and disposal or additional treatment for PAHs. PAHs would not be affected by this treatment since they are nonmagnetic organic molecules. Treatability studies are currently underway on

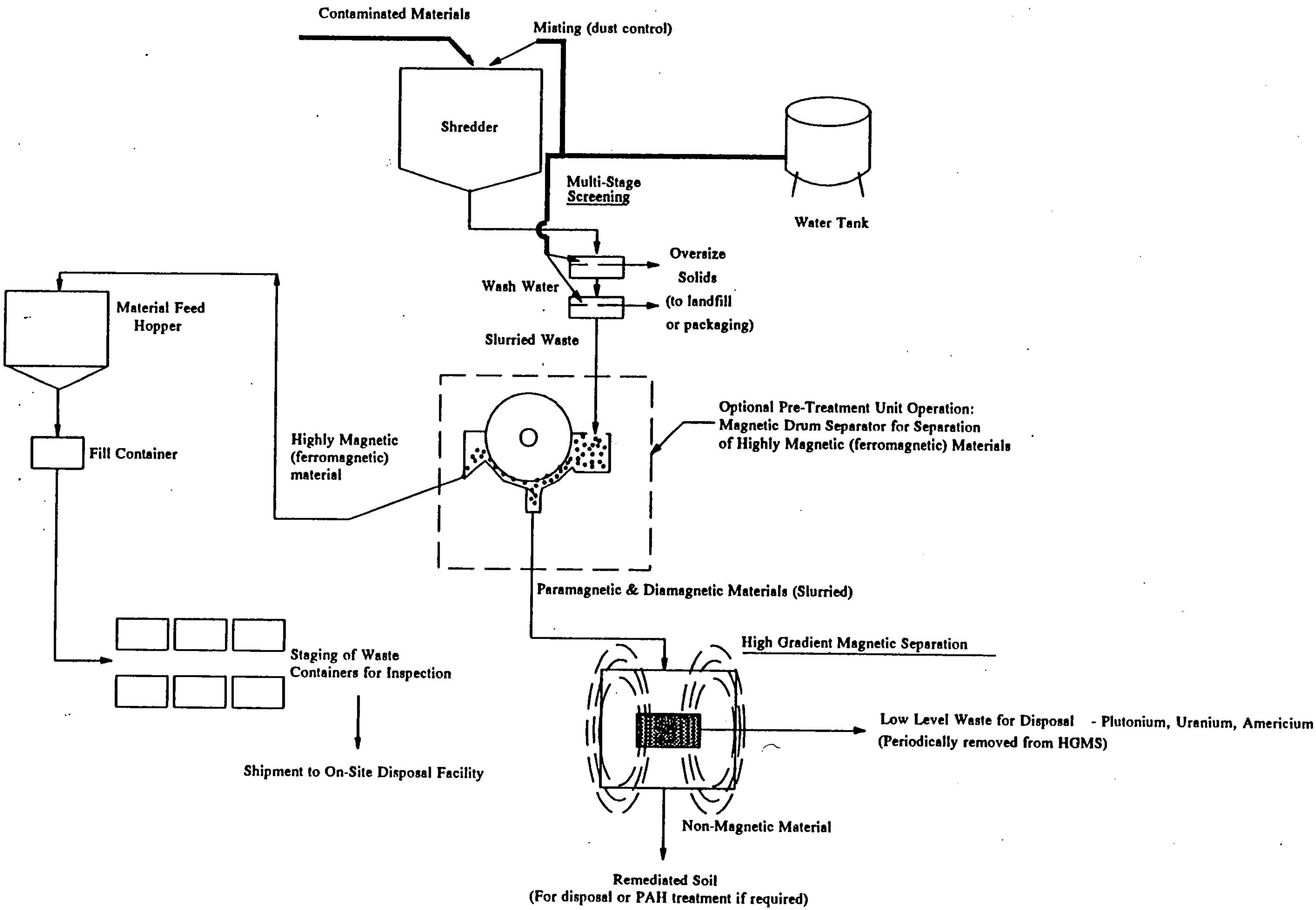


Figure I-1. Magnetic Separation Unit Operations

RFP soils in conjunction with Los Alamos National Laboratory (LANL) to determine the applicability of HGMS to RFP soils and to determine the optimal operating parameters for maximum treatment efficiency.

Segmented Gate System

The Segmented Gate System is a proprietary physical separation process from Thermo Analytical for the volume reduction of radiologically contaminated soils, sands, and sediments. It employs basic sand and gravel handling equipment, an array of radiation sensors, and a series of gates which divert contaminated material away from clean material, thus reducing the contaminated volume requiring disposal.

The contaminated material is first pre-conditioned to remove large rocks and metal debris which would interfere with the radioactivity detectors. This is done by passing the material through screens to remove rocks, then subjecting it to magnets to remove metal debris. The material is subsequently loaded onto conveyer belts. The thickness and width of material on the belts is kept constant, and the conveyer belt speed is held constant by computer control to ensure uniform assaying by the radiation detectors. The material passes under an array of overlapping radiation detectors which assay the entire volume of soil to determine radioactivity. The levels of radioactivity are recorded by a computer and compared against a preset rejection threshold. This information is fed to a control system which operates a row of piston mounted diversion gates located at the end of the conveyer belt. The clean material falls off the belt and is collected, but the control system actuates the pistons and diverts "hot" material through one or more of the diversion gates to a separate holding area. As little as one pint of material can be diverted. The process can be used alone to reduce waste volume for disposal, or combined with other radioactive soils treatments with substantial cost savings due to the decreased volume for treatment.

Thermo Analytical is currently operating a Segmented Gate System at the Defense Nuclear Agency's Johnston Atoll. They are presently processing 2400 metric tons of soil per week with an overall volume reduction of 98%. The current system has a belt speed of 30 ft/min, a waste thickness of 3/4", and a waste width of 31". The system has 15 sodium iodide detectors, which detect gamma emissions from americium molecules, arranged in an overlapping pattern to ensure assaying of all material. The current rejection threshold is approximately 13.5 pCi of total activity for any 0.1 m^3 of waste or a particle activity of 135 pCi or more. Thermo Analytical believes much lower thresholds can be achieved by decreasing waste depth and belt speed. The limiting factor in the process is the need for contamination to be significantly above background to maintain confidence in the radiological assay.

The Segmented Gate System is potentially applicable to the Rocky Flats Plant based on its potential for significantly reducing the volume of material requiring disposal or further treatment. Applicability and effectiveness will be heavily dependent on two factors: natural background radiation levels at the site, and the distribution of the contaminants within the soil matrix. Work is currently underway to determine natural background radiation levels at the RFP. Samples taken to date yield plutonium concentrations from 0.0244 to 0.100 pCi/g, but the actual background levels have not yet been determined. The difference between the background levels and the target level for contaminant removal will greatly affect process applicability and effectiveness, since the smaller the difference, the lower the level of confidence in the radiological assay. Also, since the system removes "hot" materials from the soil, contaminant distribution will also greatly impact process applicability and effectiveness. Uniform distribution will result in little or no volume reduction because either all or none of the soil will be rejected. Further characterization of the plutonium plume and treatability testing will provide information to determine the applicability and effectiveness of the Segmented Gate System to the RFP. Polynuclear aromatic hydrocarbons would likely be unaffected by this treatment since they are not seen by radiation detectors.

TRUclean

TRUclean is a proprietary soil washing process from the Lockheed Corporation for the removal of radionuclides and heavy metals from soils, sludges, and sediments. It employs soil washing, sized fractionation, and gravimetric separation techniques to reduce the volume of contaminated material. The patented process is modular, with site specific arrangements of treatment modules determined by bench scale testing. Individual modules are included and sequenced according to contaminant and media characteristics. Pilot scale tests determine optimum operating parameters.

The key component in the system is the gravimetric separation unit, which separates the material in the contaminated media based on specific gravity differences. This is done by passing the slurried media over a screen and screen bed and then exposing it to a vertical hydraulic pulse. The pulse, a sudden upflow of water through the screen and screen bed, temporarily suspends all particles in the contaminated matrix and therefore fluidizes the screen bed. Following the pulse, the water drains back through the screen and screen bed before the pulse is repeated. This cycle causes the constituent particles to fractionate based on size and density (settling velocity). Dense fine particles settle to the bottom of the screen bed, where small particles pass through the screen while larger particles collect on the screen. The dense fines are collected continuously from the bottom of the separation unit, while the oversize dense particles are collected intermittently during maintenance cycles. Less dense particles pass over the top of the screen bed and are skimmed over a weir upon exiting the gravimetric separation unit, thus being concentrated in a tailings product stream. Due to their high densities (specific gravities an order of magnitude higher than water) and relatively small particle size, radionuclides and heavy metals are concentrated in the dense fines product stream. The remediated soil is collected from the tailings and oversize dense product streams. Other unit operations in the TRUclean process are used to enhance and optimize the performance of the gravimetric separator. As mentioned earlier, the types and numbers of support processes vary based on specific media characteristics, but typically include the following: a trommel screen for initial wet screening, attrition scrubbing to promote separation of particulates from the soil aggregate, and spiral classifiers and centrifugal concentrators to "polish" the tailing stream to remove any remaining heavy metals or radionuclides. Optional hydrocyclones can also be added to fractionate out large particles and increase treatment efficiency. Figure I-2 presents a general flow diagram for the TRUclean process.

The effectiveness of the TRUclean process at RFP has been evaluated in a treatability study. The study focused on determining the effectiveness of the TRUclean process in removing

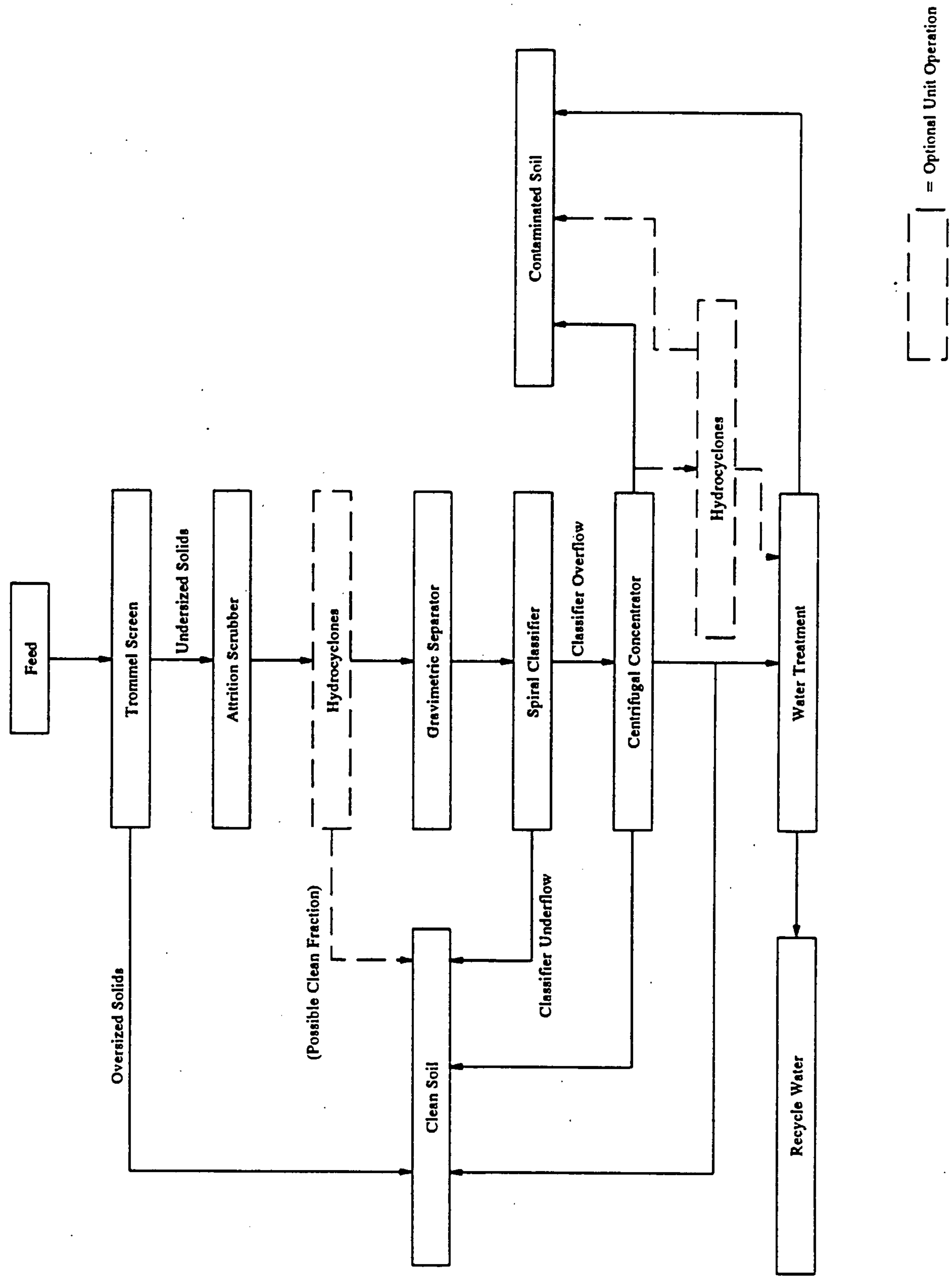


Figure I-2. General Flow Diagram for the TRUclean Process low levels of plutonium and americium contamination dispersed from the 903 pad by weathering. Results indicate that approximately 44.9 percent of the plutonium contaminated soil from the vicinity of the 903 Pad can be recovered at or below 0.9 pCi/g. Tests also indicated that natural organic matter, very common at RFP, inhibits the treatment process by formation of organo-metallic compounds with the plutonium, thus incorporating it into large, less dense molecules. Polynuclear aromatic hydrocarbons (PAHs) would tend to be unaffected by this treatment and concentrated in the remediated soil product since, due to their large molecular size and hydrophobicity, they would generally not pass through the screen of the gravimetric separator.

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
No Action	None	Not applicable	Required for consideration by NCP	Potentially applicable as a comparison against other GRAs
Institutional Controls	Monitoring	Long-term surface soil and air monitoring	Monitoring of site conditions within operable unit after remediation, or as part of an institutional control period associated with the no-action alternative	Potentially applicable for monitoring site-specific surface soil conditions (i.e. fugitive dust monitoring)
		Short-term surface soil and air monitoring	Monitoring of site conditions within operable unit during remediation activities	Potentially applicable for monitoring site-specific surface soil conditions (i.e. fugitive dust monitoring)
	Access Restrictions	Legal restrictions on access	Restrictions on present and future access to land prevent unauthorized access to contaminated areas	Potentially applicable for controlling access to areas which are subject to dust emissions or surface contamination
		Fencing or other physical barriers	Fencing, security posts, limited roads, and other various physical restrictions limit access to contaminated areas	Potentially applicable for controlling access to areas which are subject to dust emissions or surface contamination
		Legal restrictions on land use	Restrictions on present and future use and/or purchase of land; includes actions such as zoning and deed restrictions	Potentially applicable for controlling use of land which may be contaminated or subject to hazardous dust emissions

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Containment	Capping	Chemical Sealant	Chemical stabilizers are mixed with surface soils to form a stabilized cover which is resistant to water infiltration	Not applicable for remediation due to limitations on design life; not widely used or accepted in cleanups
		Clay / Soil Cap	Compacted soil and bentonite (e.g. bentomat liner) cap used to reduce water infiltration, and to mitigate erosion and dust hazards	Potentially applicable to prevent contact with surface soils which may be contaminated and to contain them in situ
		Cement - based Cap	Concrete slab over area of concern minimizes water infiltration and mitigates erosion and dust hazards	Would not be appropriate for scale required and would not provide additional protection beyond other cap types
		Asphalt - based Cap	Asphalt cover over area of concern minimizes water infiltration and mitigates erosion and dust hazards	Would not be appropriate for scale required and would not provide additional protection beyond other cap types
		Synthetic Cap	Flexible liner used as sole cover source to reduce water infiltration to subsurface, and to prevent dust emissions	Not applicable for remediation due to limitations on design life; not widely used or accepted in cleanups
		Multimedia Cap	EPA recommended cap design which contains several layers (e.g., clay, geomembrane, soil, vegetative); minimizes water infiltration, erosion, and dust emissions	Potentially applicable to prevent contact with surface soils which may be contaminated and to contain them in situ
	Erosion Control	Diversion / Runoff Control	Surface water routing measures that seek to redirect flow to minimize erosion of soils and spreading of contaminants	Not considered necessary because operable unit topography currently provides for sufficient runon/runoff control
		Wind Breaks	Mesh-like barriers used to reduce wind speeds over small areas to minimize erosion of soils and reduce dust emissions	Potentially applicable to reduce erosion rate and for dust control; however, wind breaks would not be considered a permanent solution
		Surface Armoring	Surface soils are held in place by covering with riprap or other debris; minimizes wind and water effects	Potentially applicable to reduce erosion if riprap does not interfere with remedial alternative selected
		Vegetation	Natural vegetation is used to provide a firm upper soil layer to limit dust emissions and surface water effects on soils	Potentially applicable as a natural method for erosion control; may be implemented during remediation

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Removal / Disposal	Excavation	Loader / Excavator / Dozer	Tractor/wheel mounted vehicles commonly used to excavate or move large amounts of soil; can operate at various depths	Potentially applicable for excavation of surface and subsurface soils
		Pneumatic	Vacuum extraction method for removal of loose dry surface soils or pumpable liquids into tank trucks or storage containers	Potentially applicable for excavation of surface soils; not applicable to subsurface soils
	Dust Control	Dust Suppressants	Various synthetic and natural compounds which are sprayed on surface soils to reduce fugitive dust emissions (e.g., water)	Potentially applicable to reduce dust emissions during remediation of operable unit
		Temporary Structures	Light, easily constructed structures used during remediation that provide protection from the effects of wind and rain	Not feasible because of areal extent of contamination, and not considered necessary for low levels of contamination
		Geotextile Cover	Flexible geotextile membranes that can be used during remediation to cover surface soils and reduce dust emissions	Applicability is limited because of possibility that cover would interfere with process equipment and personnel
	On-Site Disposal	Engineered On-Site Disposal Facility	On-site disposal facility designed to contain site-specific waste for a single operable unit or for the entire site	Potentially applicable for storage of contaminated surface and subsurface soils or residuals which result from the treatment of soils
	Off-Site Disposal	Permitted Off-Site Disposal Facility	Existing facility which is permitted to accept operable unit-specific waste or remedial action waste treatment residuals	Potentially applicable for storage of contaminated surface and subsurface soils or residuals which result from the treatment of soils

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
In-Situ Treatment of PAHs and PCBs	Biological	Bioremediation	Destroys organics through microbial degradation; several methods are available for treatment of PAH's	Feasibility limited for treating PAH's in surface soils due to very slow degradation rates and difficulty in process control
	Chemical	Chemical Oxidation/ Reduction	Breakdown of PAH's using chemicals which are typically introduced into the subsurface via injection wells or by spraying directly over the surface soils requiring treatment	Difficult to apply because of concerns over injecting additional chemicals into the surface soils which may result in the formation of hazardous reaction products
	Physical	Soil Flushing	Aqueous flushing agents are forced through soils via injection wells which flush contaminants into a collection system	Not feasible for large areas which require shallow soils treatment
		Vitrification	Electrical soil melting process that destroys most organics while containing other contaminants in a solid, glassy matrix	Applicability is limited by stability of hillside; also not appropriate for low levels of surface soil contamination
		Radio Frequency Heating w/ Vacuum Extraction	Radio frequency energy is applied via electrodes to heat surrounding soils thereby promoting volatilization of PAH's	Not feasible for large areas which require shallow soils treatment
		Shallow Soil Mixing	Upper layer of surface soils are mixed with lower layers to reduce contaminant exposure to erosion problems	Potentially applicable for surface soils to limit the mobility of contaminants, although may not prevent volatilization
		Vacuum Extraction	A vacuum is applied to subsurface soils to volatilize organics and remove inorganics that are in the vapor phase	Not applicable for removal of PAH's from soils in situ, PAH's do not volatilize significantly at normal temperatures
		Hot Air/Steam Stripping	Hot air or steam is injected below surface soils to force organic contaminants to the surface for capture and treatment of semi-volatile contaminants	Not feasible due to difficulty in sufficiently superheating steam to ensure adequate temperatures for volatilization of semi-volatile contaminants

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex-Situ Treatment of PAHs and PCBs	Biological	Bioremediation	Destroys organics through microbial degradation; several methods are available for treatment of PAH's	Potentially applicable for treating PAH's in excavated soils although limited by a slow degradation rate
		Land Application	Application of a thin layer of waste over an area to promote natural biodegradation; may include addition of nutrients	Not implementable because of possible radionuclide contamination in soils which would be spread during treatment
	Chemical	Ultraviolet Photolysis w/ Chemical Oxidation	UV radiation is applied to assist in oxidizing organic compounds (using various oxidizing agents), thereby destroying them	Potentially applicable for destroying PAH's in excavated soils; many aromatic reactions are UV (free radical) catalyzed
		Solvent Extraction	Removal of organic compounds from soil by mass transfer to an organic solvent which is then collected and treated	Limited feasibility for removing PAH's from soils with low contaminant concentrations; solvent would still require treatment/disposal
	Physical	Soil Washing	A variety of cleansing agents can be used to "wash" soil of organic contaminants; soils can be replaced after treatment	Potentially applicable for removing organic compounds from soil although agent would still require treatment/disposal
		Stabilization / Solidification	Binding agents are mixed with contaminated soils in either a batch or continuous process to stabilize/solidify contaminants	Not appropriate for very low levels of contamination, especially for contaminants with low initial mobility
		Incineration	Destruction of organics through oxidation and/or pyrolysis; Various methods are available (i.e. rotary kiln, fluidized bed)	Potentially applicable for treatment of PAH's and PCBs in surface soils although may not reach PRG target levels
		Thermal Desorption	Organics are volatilized from soil through the addition of heat; catalysts may be used to enhance process	Potentially applicable for treatment of PAH's and PCBs in surface soils although may not reach PRG target levels
		Vitrification	Electrical soil melting process that destroys most organics while containing other contaminants in a solid, glassy matrix	Potentially applicable for treatment of excavated soils, but may not be appropriate for low levels of contamination
		Molten Salt / Sodium Fluxing	Molten salt, air, and soil are combined in a reactor to destroy organics through oxidation and to trap halogens	Not applicable for treatment of PAHs, more commonly used for remediating chlorinated solvent contamination

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
In-Situ Treatment of Radionuclides	Physical	Soil Flushing	Complexing or chelating agents are used to solubilize radionuclides and then extracting the contaminated flushing solution	Difficult to apply because of concerns over solubilizing radionuclides which could then migrate toward groundwater
		Stabilization / Solidification	Binding agents are injected into contaminated soils and then harden to stabilize/solidify contaminants	Difficult to implement due to large surface area and minimal depth of contamination
		Shallow Soil Mixing	Upper layer of surface soils are mixed with lower layers to reduce contaminant exposure to erosion problems	Potentially applicable for surface soils to limit the mobility of contaminants and to reduce potential human exposure levels
	Thermal	Vitrification	Electrical soil melting process that encapsulates radionuclides and other contaminants in a solid, glassy matrix	Applicability is limited by stability of hillside; also not appropriate for low levels of surface soil contamination or large, shallow areas
Ex-Situ Treatment of Radionuclides	Physical	Soil Washing	A variety of cleansing agents can be used to "wash" soil of radionuclides; soils can be replaced after treatment	Potentially applicable for excavated surface soils although "wash" solution would require additional treatment/disposal
		Stabilization / Solidification	Binding agents are mixed with contaminated soils in either a batch or continuous process to stabilize/solidify contaminants	Potentially applicable for excavated surface soils contaminated with radionuclides
		Manganese Dioxide Adsorption	Radionuclides are adsorbed from slurried soil onto manganese dioxide particles	Not feasible due to its experimental nature and the extent of research and treatability studies it would require; thus it has been screened out from RFP Sitewide treatability studies
		Magnetic Separation	A high gradient magnetic field is applied to slurried soil which forces polar radioncuclides out of slurry onto collector plates	Potentially applicable for excavated surface soils; currently undergoing treatability studies at the Los Alamos National Laboratory
		TRU-Clean (proprietary process)	Radionuclides are "washed" from slurried soils by a proprietary precipitation process	Potentially applicable for excavated surface soils; currently undergoing treatability studies at the Nevada Test Site
		Segmented Gate System	Radioactive particles above threshold activities are removed from soil and concentrated by diversion gates attached to radiation monitors	Potentially applicable for excavated surface soils. May exhibit low treatment efficiency on fine, well-distributed radiation sources such as those at OU1
	Thermal	Vitrification	Electrical soil melting process that encapsulates radionuclides and other contaminants in a solid, glassy matrix	Potentially applicable for excavated surface soils contaminated with radionuclides

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability, applicability, or feasibility

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
EVALUATION OF PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	*REMEDIAL TECHNOLOGY*	*PROCESS OPTION*	*EFFECTIVENESS*	*IMPLEMENTABILITY*	*RELATIVE COST*
Removal / Disposal	Excavation	Loader / Excavator / Dozer	Effective for excavating soils and sludges less than 30 feet deep	Readily implementable; uses common road building and construction equipment	Low Capital Moderate O & M
		Pneumatic	Effective in removing loose, dry soils or pumpable liquids from ground surfaces and surface waters	Readily implementable	Low Capital Low O & M
	Dust Control	Dust Suppressants	Moderately effective for reducing surface dust generation depending on type of suppressant	Readily implementable although certain suppressants may be considered hazardous	Low Capital Moderate O & M
	On-Site Disposal	Engineered On-Site Disposal Facility	Effective in containing treated or residual wastes assuming the facility is designed properly	Difficult to implement because of permit requirements and administrative concerns	Very High Capital High O & M
	Off-Site Disposal	Permitted Off-Site Disposal Facility	Effective in containing treated or residual wastes if proper facility is available	Readily implementable for wastes other than TRU or mixed (radioactive/hazardous)	Moderate Capital Very Low O & M

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
EVALUATION OF PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
In-Situ Treatment of PAHs and PCBs	Biological	Bioremediation	Effective in treating organics but difficult to monitor progress during in situ treatment; may result in residuals which require further treatment	Requires extensive treatability work to determine viability of microbial growth	Moderate Capital Moderate O & M
	Physical	Shallow Soil Mixing	Effective in treating upper soil layers in situ to prevent migration of contaminants	Readily implementable; uses commonly available agricultural engineering equipment	Low Capital Moderate O & M
Ex-Situ Treatment of PAHs and PCBs	Biological	Bioremediation	Effective in treating organics but may possibly result in residuals which require further treatment	Requires extensive treatability work to determine viability of microbial growth	Moderate Capital Moderate O & M
	Chemical	Ultraviolet Photolysis w/Chemical Oxidation	Effective method for destroying some organic compounds depending on UV lamp used in system	Implementability will depend on oxidation method chosen to accompany UV process	High Capital High O & M
		Solvent Extraction	Effective in removing volatile and non-volatile organic compounds from soils although spent solvent will require treatment or disposal	Moderately difficult to implement relative to other ex situ treatment options	High Capital Moderate O & M
	Physical	Soil Washing	Effective for removal of organic and inorganic contaminants; several washing agents available	Implementable technology which is based on commonly used ore mining technologies	High Capital Moderate O & M
		Incineration	Effective in destroying or removing organic contaminants to levels in the low ppm range	Implementable technology which has been used extensively for treating organics	High Capital High O & M
		Thermal Desorption	Effective for removing volatile and semi-volatile compounds from soil; requires off-gas treatment	Implementable technology which has been used extensively for treating organics	High Capital High O & M
		Vitrification	Very effective for destroying organic waste while containing other contaminants such as metals	Innovative technology which is difficult to implement based on the complexity of equipment required to vitrify waste	Very High Capital Very High O & M

ROCKY FLATS PLANT - 881 HILLSIDE (OPERABLE UNIT 1) CMS/FS
EVALUATION OF PROCESS OPTIONS
(SOILS)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
In-Situ Treatment of Radionuclides	Physical	Soil Flushing	Innovative technology which is effective for removing certain radionuclides from soil particles	Moderately difficult to implement; requires a system to collect and treat flushing agent	High Capital Moderate O & M
		Shallow Soil Mixing	Effective in stabilizing upper layer of soils in situ to prevent migration/contact with radionuclides	Readily implementable; uses commonly available construction equipment	High Capital High O & M
Ex-Situ Treatment of Radionuclides	Physical	Soil Washing	Effective for removal of radionuclides from soil if proper washing agents are used in the process	Implementable technology which is based on commonly used ore mining technologies	High Capital Moderate O & M
		Stabilization/ Solidification	Effective in containing radionuclides by containing them in a stabilized or solidified matrix	Moderately difficult to implement because of problems with long-term leach resistance	Moderate Capital Moderate O & M
		Magnetic Separation	Effective for removing trace amounts of metals from liquid waste streams, including radionuclides	Moderately difficult to implement	Moderate Capital Moderate O & M
		TRU-Clean (proprietary process)	Innovative, proprietary process which is a form of soil washing used specifically with rad metals	Readily implementable but requires consent of proprietary vendor for implementation	High Capital Moderate O & M
		Segmented Gate System	Effective for removal of discrete radioactive particles. Effectiveness for contaminants distributed by weathering would be determined by treatability studies	Readily implementable. Uses common sand-and-gravel handling equipment and common radiation monitors. Control software and design are proprietary	Low Capital Moderate O & M
	Thermal	Vitrification	Very effective for containing radionuclides in a glassy solid matrix which is resistant to leaching	Innovative technology which is difficult to implement based on its complexity	Very High Capital Very High O & M